In this way the danger of eventual corrosion of the steel rings by soil acids which could penetrate through the cracks, is eliminated.

After this operation the pipe can be covered with soil.

It is true that stainless steel is more expensive than ordinary steel, but this is counterbalanced by the fact, that there is no (or only very little) additional steel thickness needed for rust-allowance.

As is customary in Indonesia, a thickness of 2 mm is taken for rust allowance for ordinary steel. With "Cor-Ten" steel we can safely take herefore ½ mm or at most 1 mm.

With a total thickness of 3 mm for the internal cylinder the use of "Cor-Ten" steel means a gain in useful thickness of at least 100%, viz. 2 mm out of 3 mm with "Cor-Ten" against 1 mm out of 3 mm with ordinary steel.

The gain in plate thickness obtained in this way offsets amply, particularly in the case of thin plates, the higher cost, which is higher by about 20% only. Furthermore the tensile strength of "Cor-Ten" steel is about 30% higher than that of normal steel.

And if one sticks to the same rust-allowance thickness of ordinary steel, this means a considerable increase of lifetime and a great decrease in maintenance. This is the more so because the steel cylinder is exposed only on the waterside (or oilside in the case of oil pipes), while on the more dangerous air-side concrete only is present.

Further the following short example of calculation may give one an idea as to the internal pressures that the new type of pipe can withstand.

Suppose that the internal diameter of the pipe is 100 cm. Assume a steel thickness of 2 mm of which 1 mm is rust-allowance. The useful plate thickness is thus 1 mm.

Take a circumferential reinforcement consisting of 13 rings per m length of pipe with a rod diameter of 3 cm. The concrete thickness is 11 cm.

The effective cross-sectional area of steel (A_s) per 100 cm of pipe length is thus:

internal cylinder :	100 × 0.1 cm^2 =	10.0 cm^2
rings .... :	13 × 7.07 cm^2 =	92.0 cm^2
A_s = total		102.0 cm^2 (16.3 in^2.)

With the hoop-stress formula the internal pressure p (atm.) can now be calculated:

$$100\,p = \frac{A_s\,T_s}{r}, \quad \text{where: } T_s = \text{allowable steel stress} = 1200\ kg/cm^2 = 16{,}500\ lbs/in^2$$

$$r = \text{internal radius of pipe} = 50\ cm$$

$$\text{Therefore } 100\,p = \frac{102 \times 1200}{50}$$

$$p = 24.5\ \text{atm.} = 360\ \text{psi.}$$

$$\text{or} \quad p = 245\ m \text{ or } 800\ ft \text{ of water.}$$

A pipe with an internal diameter of 50 cm, which is often used for underground pressure-pipes for oil- or gas-transport can withstand, with the same cross sectional area of steel, an internal pressure of 2×24.5 atm. = 49 atm. (= 720 psi = 490 m or 1600 ft of water). If in the case of the 100 cm diameter pipe the number of rings is doubled, the total cross sectional area of steel becomes. (per 100 cm pipe length):

$$10\ cm^2 + 2 \times 92\ cm^2 = 194\ cm^2$$

$$\text{We then have: } 100\,p = \frac{194 \times 1200}{50}$$

$$p = 46.5\ \text{atm.} = 653\ \text{psi}$$

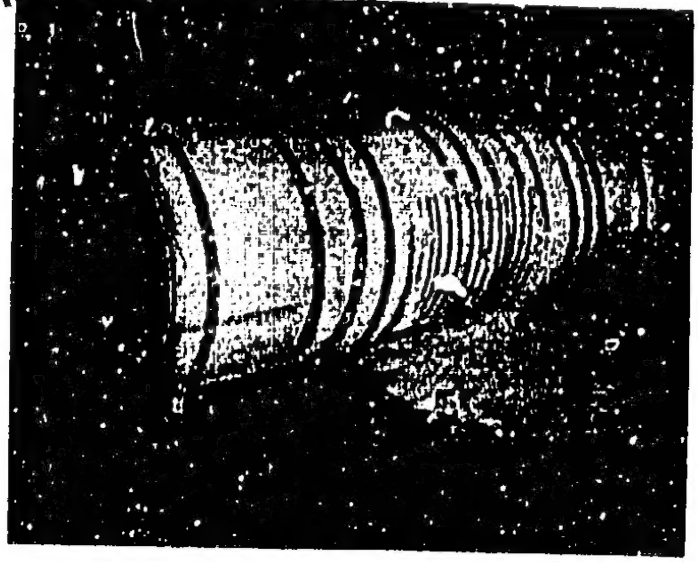
$$= 465\ m \text{ or } 1525\ ft \text{ of water.}$$

In this case the concrete thickness is 17.5 cm. If out of this pipe the steel internal tube is taken away so that we get in effect an ordinary reinforced concrete pipe of 100 cm diameter and 17.5 cm wall thickness, then with an allowable tensile stress of 10 kg/cm^2 for the concrete, the allowable internal pressure for the pipe is only 9 atm or 90 m of water which is thus less than 20% of the allowable internal pressure for the same pipe fitted with a steel internal cylinder.

And the difference is still greater with respect to safety against leakages.

For still higher heads the use of high quality steel for the circumferential reinforcement is recommended.

From the foregoing it is clear what important and many sided functions are performed by the stainless steel internal cylinder in the new pipe system, quite in contrast to the role of the steel core-tube in other type reinforced concrete pipes, viz. only an additional safety measure against leakage.



Test-pipe in full scale

E. TESTING IN FULL SCALE

Concludingly I want to note that a test pipe of 3 m length and a diameter of 90 cm, designed in the same way for an internal pressure of 20 atm. (294 psi), broke down only at 61 atm. (880 psi = 610 m or 2000 ft of water), and this was mainly due to imperfect welding of the 1 inch diameter steel rings (see photo).

It should be marked here that the concrete was of normal quality and ordinary mixture of 1 : 2 : 3.

The thickness of the concrete cylinder is 10 cm.

The internal steel cylinder was of ordinary steel with 3 mm thickness.

During the test the pipe wall remained absolutely watertight.

After the test the steel internal tube appeared to be completely whole.

The first little cracks in the concrete appeared only after 50 atm test pressure. Then the steel begin to yield.

In this test it is clearly shown that statically the concrete did not play an important role.

F. PRACTICAL APPLICATIONS

The new system of penstock as proposed by author is first put into practice in the construction of the hydro-power station of Golang in Java, Indonesia.

[illegible] consists of 2 pipes each 400 m long and 100 cm in diameter. The concrete thickness is 10 cm. The internal steel tube is made of "Cor-Ten" steel 3 mm in thickness. The maximum head is 120 m. Only the distributing pipe which connects with the turbines is made of steel (see accompanying figure).

Summary

The pro's and con's of reinforced concrete for pressure pipes are briefly outlined.

Further some existing systems for pressure pipes are discussed, whereby the essential features of each system is brought forward.

Finally a new type pressure pipe is developed suitable for very high heads, which possesses, besides absolute water-and air-tightness, great strength against positive as well as negative pressure surges (water hammer).

It is feasable for small as well as for large diameters against any gradient and can for conduits of not too great lengths be cast-in-place without expansion joints.

Therefore this system is very suitable not only for penstocks for hydro-power plants but also for underground pressure conduits for oil- or gas-transport.

Résumé

Les avantages et les inconvénients du béton armé pour les conduites forcées sont brièvement définis.

Quelques autres systèmes de conduites forcées en usage sont aussi discutés, de façon à mettre en évidence les caractéristiques essentielles de chacun d'eux.

Finalement, un nouveau type de conduite forcée est exposé, propre pour de très fortes pressions et qui possède en outre une parfaite étanchéité à l'eau et à l'air, une résistance très forte aux coups-de-bélier positifs ou négatifs.

Ce type peut être construit pour les petits comme pour les grands diamètres, avec n'importe quelle inclinaison, et, pour des conduites de longueur moyenne, peut être préparé sur place sur place sans joints d'expansion.

Ce système convient donc fort bien, non seulement aux tuyaux d'alimentation de centrales hydro-électriques mais aussi aux conduites forcées souterraines pour le transport d'huile ou de gaz.

Resumo

As vantagens e os inconvenientes do concreto armado para os condutos forçados (encanamentos de pressão) são brevementes descritos nessa monografia.

Além disso, discutem-se alguns sistemas atuais para êsses condutos, pelo que se evidenciam os principais característicos de cada sistema.

Finalmente, ùm novo tipo de conduto forçado é descrito, próprio para pressões muito fortes, além de sua absoluta impermeabilidade ao ar e à água, e grande resistência às ondas de sobretensão, tanto positivas como negativas (golpe de ariete).

Esse tipo é praticável para pequenos e grandes diâmetros em qualquer inclinação, e pode, para condutos forçados, de não muito grande comprimento, ser colocado sem juntas de dilatação.

Por conseguinte, êsse sistema é muito adequado, não só para açudes de centrais hidro-elétricas, como para os condutos forçados subterrâneos de transporte de óleo ou de gás.

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THE INFLUENCE OF GASEOUS FUELS ON MODERN INDUSTRY

By FRANCESCO ROMA

Professor at the University of Bologna, President of the Technical Council of the National Association for The Control of Combustion

ITALIAN NATIONAL COMMITTEE

INTRODUCTION

Gaseous fuels are to be considered among the most valuable sources of power at the disposal of industry for the purpose of combustion processes as well as for the special processes based on chemical transformations which yield compounds involving a big range of the economic tions which yield compounds involving a big range of the economica field.

This report will be a quick review of the influence of gaseous fuels on Ital's industrial progress in the last period, with special stress given to natural gas which represents the richest resource of the Italian subsoil.

Italy up to a few years ago used almost exclusively a gas obtained from the processing of foreign or national solid fuels.

For several years a noticeable variation in the utilisation of the various Italian power sources has been taking place, towards both the growth of petroleum refineries and exploitation of the natural gas.

Data on Tab. I show the petroleum refineries and the natural gas contribution to the solution of the Italian power problems.

Tab. II shows the domestic production and the foreign purchase of solide fuels in the last three years.

Tab. III gives amount of solid fuels utilized for distillation.

From Tab. III it is seen that in Italy at present more than 46% of the total amount of solid fuels is distilled to yield gas and coke. While the gas and coke produced by gasworks are mainly for household use of the gas produced by cokeries up to 60% is used for chemical synthesis, especially for the manufacturing of synthetic ammonia and the remaining 40% for metallurgical purposes.

TABLE I

Division of the power consuption in Italy

Year	Solid fuel %	Liquid fuel %	Natural gas %	Liquefied petroleum gases %	Electric power %	Total	Total index (1938=100)
1938	53,2	6,9	---	---	39,9	100	100
1950	36,1	11,0	2,2	---	50,7	100	119
1951	33,0	12,0	3,5	0,3	51,2	100	142
1952	30,5	12,2	5,0	0,6	51,7	100	146

The utilisation of the synthesis gas yielded by the distillation of solid fuel is carried on in four big plants of the following companies: Cokitalia (S. Giuseppe di Cairo); Cokapuania (Apuania); Vetrocoke (Marghera) and Terni (Nera Montoro).

TABLE II

Italian production and foreign purchase of solid fuels
(,000 t comparison to 7,700 kcal/kg)

Year	1950	1951	1952
Italian production	1,155	1,296	1,222
Foreign purchase	8,411	10,789	9,206
Total	9,566	12,085	10,428

TABLE III

Amounts of solid fuels distiled or gasified and amounts of gas yielded

Year	1950		1951		1952	
	,000 t	%	,000 t	%	,000 t	%
Solid fuel distilled or gasifield:						
By gasworks	1,429	42,2	1,545	35,3	1,612	33,2
By coheries	1,957	57,8	2,839	64,7	3,221	66,8
Total	3,386	100,0	4,384	100,0	4,833	100,0
Gas yield:						
By gasworks	991	61,5	1,013	54,2	1,050	51,7
By coheries	626	38,5	859	45,8	982	48,3
Total	1,617	100,0	1,872	100,0	2,032	100,0

[illegible] owing to the scarce utilisation of the coke produced by the gasworks, attention has been drawn to double gasification by which the distillation of the solid fuel and the gasification with steam of the residual coke are carried on in the same gas producer. These concurrent operations result in a noticeable economic advantage from the point of view of the total thermic efficiency as well as for the lower investment costs and lower costs of operation.

The double gas has an average heating value of 3,100 kcal/normal cu.m.

In Italy after the II World War four big double gasification plants based on the Viag process have been operated at the gasworks in Rome (Società Italiana Gas), in Milan (Società Edison), in Naples (Società Napoletana Gas) and in Trieste (Municipality) with a total yield of 480,000 cu.m. of gas a day. The most important of the four is the one at the Rome gasworks which yields about half of the total. The national distribution network has a total lenght of 11,000 km.

Regarding liquid fuels Tab. IV shows the production of Italian refineries in the last three years.

The use of crude oil for gas production in Italy is still in its early stages but undoubtedly a great increase will occur.

Some plants now nearly completed and based on different processes, will carry out the carburation of the double gas to increase its heating value from 3,100 kcal/Normal cu.m. to 4,200 kcal/Normal cu.m.

All the processes are of U. S. origin and at present the first plant following the Semet-Solvay process is being built at the Rome gasworks for producing high heating value gas from oil, while a Segas process catalytic plant is in operation at the Verona gasworks to meet the peak period.

Also worth noticing is the use of liquefied petroleum gases (butane and propane) for household appliances. In 1952 the total amount was 120,897 tons of which 65,803 were produced by the Italian petroleum refineries and by the AGIP's powerful gasoline plant located on the natural gas wells at Cortemaggiore the remainder being of foreign purchase.

Present state of Italy's natural gas production and consumption

Italy's natural gas production, which is becoming a more and more notable percentage of the national power production, was rather negligible till a few years ago.

The Italian Government realising the importance that this new source of power would constitute for the national economy, established the AGIP — Azienda Generale Italiana Petroli — as far back as 1926 with the aim of investigating and drilling the national subsoil for liquid and gaseous hydrocarbons.

TABLE

Production of the Italian refineries (.000 t)

Year	Production		Division of the utilisations					
	.000 m3	Index 1938 = 100	Utilisation as a fuel		Industrial and house hold utilisations		Consumption in mines	
			.000 m3	% on total	.000 m3	% on total	.000 m3	% on total
1938	17,111	100,0	4,389	25,6	1,528	8,9	11,213	65,5
1939	20,224	118,2	9,062	44,8	1,681	8,3	9,481	46,9
1940	27,766	162,3	16,740	60,3	2,315	8,3	8,711	31,4
1941	42,168	246,4	30,650	72,7	2,917	6,9	8,601	20,4
1942	54,699	319,7	43,294	79,1	3,827	7,0	7,578	13,9
1943	54,959	321,4	43,506	79,1	4,124	7,5	7,339	13,4
1944	49,225	287,7	39,726	80,7	4,447	9,0	5,052	10,3
1945	41,899	244,9	31,156	74,4	6,505	15,5	4,228	10,1
1946	64,500	377,0	40,000	75,0	9,100	17,1	4,200	7,9
1947	98,680	576,7	50,760	66,9	22,800	27,9	4,250	5,2
1948	135,810	793,7	56,074	53,4	45,199	43,1	3.640	3,5
1949	233,741	1,366,0	68,097	29,1	162,631	69,6	3,013	1,31
1950	501,147	2,933,6	80,644	16,1	415,149	82,84	5,354	1,06
1951	943,506	5,514,0	121,635	12,83	815,331	86,41	6,540	0,7
1952	1,412,677	8,255,9	147,604	10,45	1,257,418	89,0	7,651	0,55

In 1938 AGIP's researches were succeful at Fonteviss (Parma) and at Podenzano (Piacenza) so assuring the existence of gas fields in the Po valley at a depth of 800 to 1.000 m. The Podenzano wells were connected to Milan with a gas pipe-line 70 km long with a diameter of 88 mm, to serve some natural gas compression and distribution plants. The wells were exhausted after 200,000,000 cu.m of natural gas had been exploited.

In 1941 the AGIP pursuing in its research plan with improved and more powerful equipment, reached 1.300 m at Caviaga, near Lodi, discovering a much more significant field than the former. This result led to the extension of the research to the whole of the Po valley.

AGIP's plan was discontinued during the war but was resumed soon after its end with a wider programme, and in 1946 the drilling of a second well at Caviaga was completed. In the following years the Cortemaggiore, Ripalta, Conegliano, Bordolano, Correggio, Ravenna and Rapagnano fields were located obtaining results which surpassed the most optimistic forecasts.

Recently the Ente Nazionale Idrocarburi — E. N. I. — has been established with the aim of coordinating all Government enterprises in the national field of liquid and gaseous hydrocarbons fitting them into a general framework.

At present due to the Government and private companies a large plan of research and drillings is carried on, not only in the Po valley but also in the rest of the country.

The capacity of the Italian gaseous fields now under recovery is valued at 80 to 100,000,000,000 cu.m. which correspond to a consumption of 4 to 5,000,000,000 cu.m. for a period of 20 years.

Natural gas production in 1938 was confined to 17,000,000 cu.m. while in 1952 it reached 1,400,000,000 cu.m. and is foreseen to reach 2,300,000,000 cu.m. in 1953.

The percentage of natural gas consumption in the national power consumption reached 5% in 1952, corresponding to 1,734,000 tons of solid fuel with heating value of 7,700 kcal/kg (see Tab. I and Tab. II).

The gas transportation and distribution to the various consumers is performed for a negligible amount by means of cylinders and the remaining quantity is transported and distributed by means of a gas pipe-line network reaching a total lenght, in 1952, of 2,905 km; 2,105 of which are main pipe-lines. This network already connects the main industrial locations of Northern Italy, i.e. Piedmont, Lombardy, Liguria, Venetia, Emilia and Tuscany.

Gas pipe-line start from the big fields of Caviaga, Cortemaggiore, Conegliano, Ripalta, Bordolano, Corregio, Pontenure in Emilia and Lombardy, and from the Polesine wells to reach the consumption locations of Turim, Milan, Marghera, Ferrara, Bologna, Florence and in a short time also Genoa.

The following companies manage the national gas pipe-lines network:

SNAM — Società Nazionale Metanodotti	2,064 km
AMP — Azienda Metanodotti Padani	639 km
SIN — Società Idrocarburi Nazionali	154 km
Minor companies	48 km

SNAM network which carries and distributes the natural gas recovered in AGIP's fields has a transportation capacity of 13,000,000 cu.m./a day, capacity that will be increased to over 20,000,000 cu.m. in 1954 as soon as the work on the net is completed, and the total lenght will be over 5,000 km.

Particular attention is to be given to the gas pipe-line connecting Cortemaggiore to Turin the lenght of which is 210 km and the diameter 420 mm, which is the biggest in Europe.

AMP's network which, as mentioned before, distributes the natural gas recovered from the Po delta wells, has a transportation capacity of 2,000,000 cu.m. a day.

The SIN manages a gas pipe-line which connects the Po delta fields with the Appenine Tuscan-Emilian field, which at the moment is nearly exhausted, and with Florence where a small quantity of the gas is passed to several industries and the remainder is compressed in cylinders and distributed for road transport purposes.

The natural gas transported in the main pipe-lines built of welded carbon steel Mannesmann tubes, runs at a pressure of about 40 ÷ 60 kg/sq.cm. On the distribution pipe-line branches the natural gas runs at a pressure of about 12 ÷ 15 kg/sq.cm.

Industrial plants are furnished with pressure regulating devices by which pressure is reduced to 0.5 ÷ 1.5 kg/sq.cm.; the amount of gas being measured by means of gas meters. Then the gas is distributed to the different locations where the gas is utilised with in the plant itself.

Natural gas is nowadays used for road transport purposes and in such cases it is compressed in cylinders; it is also used for household

TABLE VI

~~Production and consumption of natural gas in Italy.~~

Natural Gas

Area of consumption	1950		1951		1952	
	10^3 m3	%	10^3 m3	%	10^3 m3	%
Industrial utilisations						
Food and agricultural	18,000,0	3,59	34,376,3	3,64	67,984,1	4,81
Metallurgical and ironworking	124,476,9	24,84	221,351,3	23,47	253,236,0	17,93
Mechanicalworks	9,006,7	1,80	30,636,1	3,24	98,022,5	6,95
Paperworks	7,192,0	1,44	32,228,1	3,41	50,063,0	3,54
Textiles	29,737,1	5,93	127,445,2	13,51	203,695,9	14,43
Building materials	9,814,7	1,96	21,803,3	2,31	56,844,2	4,02
Glassworks	15,276,0	3,05	54,411,0	5,77	62,776,2	4,40
Chemical	84,389,4	16,84	146,129,0	15,49	207,686,6	14,7[illegible]
Electric	42,209,4	8,62	39,386,6	4,17	97,435,6	[illegible]
Various	43,396,6	8,64	65,269,0	6,92	82,671,1	5,85
Total	384,428,8	76,71	773,036,1	81,95	1,183,357,2	83,55
Household utilisations	30,739,8	6,13	42,294,8	4,48	77,060,4	5,45
Utilisations for road transport purposes	80,644,7	16,09	121,435,6	12,89	147,608,5	10,45
Mine consumption	5,353,9	1,07	6,540,7	0,70	7,65[illegible],7	0,55
Total of utilisations	501,147,2	100,00	943,507,2	100,00	1,412,677,9	100,00
Losses in mine and in transportation	20,373,5		27,757,9		22,570,2	
Total gas distributed	521,520,7		971,265,1		1,435,248,1	

purposes either alone or mixed with the city gas; sometimes it is used for these purposes pretreated.

The most significant utilisation takes place in the industrial area for the generation of electric power, as a raw material for the chemical industry, and finally as a thermic source in various technical processes (See Tab. V and Tab. VI).

The Italian natural gas is chiefly composed of methane to which in different amounts other gases may be mixed, namely higher hydrocarbons (ethane, propane, butane), or nitrogen, carbon dioxide, oxygen etc.

TABLE IV

Natural gas utilisation during the years 1950 — 1981 — 1952

Year	1950	1951	1952
Crude processed	5,352	487	9,830
Main products:			
Gasoline	984	1,366	1,781
Kerosene	299	467	615
Gasoil	1,040	1,440	1,814
Fuel oil	2,479	3,582	4,789
of which exported			
Gasoline	282	455	786
Kerosene	125	165	317
Gasoil	198	384	665
Residues	343	373	,087

Mixed in the gas pipe-lines, the gas at disposal for utilisation has an average net heating value of 8,100 ÷ 8,200 kcal/cu.m. at 15°C and 760 mm Hg.

Natural gas used as a fuel in kilns and in steam generating plants for heating purposes and for the production of electric power.

The advantages issuing from a gas combustion are well known and foremost among them are: the possibility of preheating the gas and the air required for the combustion, by this treatment it is possible to increase the combustion temperature; the possibility of proportioning the required combustion air in a very close manner to the theoretical amount

required, and reaching by this way high temperatures and at the same time a high combustion efficiency lowering to the minimum the fund..-mental loss which is incidental to each kind of furnace, that is to say the loss of sensible heat at the stack.

Another advantage correlated to utilisation of gas is the easiness of its regulation, that is to say the possibility of equalizing the combustion to the requirements of the batch and of the production.

In the specific case of natural gas, some of these characteristics are outstanding in comparison with those of other gases. The natural gas combustion, without preheating either the gas or the air yields a high combustion temperature which satisfies a wide range of technologies; whereas in some cases it is necessary to brake this pirometric effect as some technologies do not require the high temperature normally yielded by the natural gas combustion.

The theoretical peak temperature of pure methane is established by some technicians at 1.900°C and by others at 2.000°C.

The average temperature reached in pratice is about 1.400°C. without need of air or gas preheating.

As is already known the heat transfer in industrial kilns takes place by irradiation conduction and convection. The first place regarding capacity to transfer heat by irradiation is held by coal and particularly by pulverized coal, the second place is maintained by fuel oil followed by gases, first of which is methane and last of all low grade gas except when it contains tar or other hydrocarbons.

These conclusions have been confirmed by means of practical tests. In fact if in a furnace fuel oil combustion is replaced by methane combustion, the results are highly satisfactory in many respects, but if it is necessary to maintain the same rate in the transformation of the technological product, especially in operations based prevalently on the transfer of heat by irradiation, it is necessary to adopt some cautions and to provide for some adaptions.

Results of direct tests, carried out by eminent investigators, have confirmed the lower capacity of irradiation in the case of methane combustion and the requirement of arrangements to improve this side of the problem.

Methane combustion with a shortage of air can give a brilliant flame. The resulting flame has a suspension of coal particles which, consequently incandescent at the high temperature achieved, irradiate heat, giving to the flame a particular brightness. But obviously combustion with shortage of air is a low efficiency combustion as a part of the fuel escapes in the fuels unburnt.

Another method for to achieving the brightness of the flame is to crack methane, in the same way as fuel oil is cracked at about 500 ÷ 600°C.

It is well known that the cracking produces carbon particles which act in the same way as described above.

[illegible] in normal conditions is complete at about 1,500°C, but starts at a somewhat lower temperature, and for this reason if the gas is preheated at about 800°C a partial decomposition is achieved with formation of carbon particles.

In this way the problem is solved, as the flame irradiance is increased without affecting the combustion efficiency and because of the high heating value of the gas it is possible to free a very high and concentrated amount of heat.

Another method that is now being widely applied especially in the ironworking industry is to introduce in the natural gas heavy hydrocarbons which are more easily cracked. If a small amount of fuel oil is added to the natural gas it is possible to achieve the effect more easily than by cracking the natural gas alone. Fuel oil injections are made as they are quite easily put into practice, but it would also be possible to achieve the same result by the introduction of any pulverized solid fuel into the gas.

One of the fundamental conceptions to keep in mind in the designing of burners for natural gas, as for any other fuel, is to obtain a complete mixture between air and fuel. This is achieved by giving the maximum of turbulent flow to the gas or to the air or to their mixture.

To comply with this characteristic several devices are worked out, and the Italian manufacturers, taking account of the experience acquired with other gases, are able to produce different kinds of appliances, which successfully achieve the turbulent flow and the mixture mentioned above.

Another point to be kept in evidence is the burner gas flow rate, which has to be such that the flame will neither lift nor backfire.

The simplest kind of burner is the atmospheric one, in which the natural gas brings about a suction of the required combustion air and a complete mixture between antural gas and air is so achieved.

In the performance of this very simple kind of burner, the air surrounds the gas and a very smooth and long flame is obtained allowing the combustion to go on gradually. It is an inexpensive arrangement, but obviously to deal with the combustion of large amounts of gas more than one single burner is required.

Another device is operated on the premixing of air and of gas, obviously within limits that do not give rise to danger from explosions.

In accordance with the leading principles before stated several Italian plants have been transformed and others are being specially built for natural gas utilization.

The transformation concerns steam power plants, ironworking kilns, cement rotary furnaces, limekilns, glasswork furnaces, ceramicworks furnaces etc.

Several steam boilers are at present natural gas operated, and two big power plants, Tavazzano (Società Termoelettrica Italiana) and Piacenza (Società Edison) are already run on natural gas. Other power plants are being planned.

The Tavazzano plant is furnished with two turbine generators each of 65,000 kW and two steam boilers each of 215 tons per hour with a working pressure at superheater outlet of 125 kg/sq.c. and a final steam temperature of 510°C with reheating. A recent running test steted a net consumption of 2,350 kcal/kWh that is to say with all internal plant consumption deducted. This consumption is the lowest achieved in Europe to-day.

Another characteristic of the Tavazzano power plant is the application of a turbine regulating the pressure of the gas to be burnt in the boilers. The gas delivered by the gas pipe-line at a pressure of 50 ÷ 40 kg/sq.cm. is flashed at 1.2 kg/sq.cm. gauge in a turbine connected with an electric power generator. This supplementary plant yields further power which amounts to 1.2% of the total yielded.

Also the power plant of the Edison Company at Piacenza is furnished with two turbine generators each of 70,000 kW, fed with steam at a temperature of 538°C and at a pressure of 105 kg/sq.cm., produced by two natural gas burning steam boilers equipped with a reheater as in the former case; this plant was first operated during the year 1953 achieving very successful results.

The biggest Italian ironworking and engineering industries use natural gas in the steel refining furnaces such as the open hearth furnaces, in soaking pits and in many other operations.

Already adapted for the use of natural gas are the Dalmine steelworks, the biggest Italian tube manufacturing firm; the Falk and Breda steelworks in Milan, Franco Tosi's huge engineering plants in Legnano; the steelworks and engineering plants of FIAT which is the biggest Italian firm for motor vehicles building.

Also some of the rotary furnaces of cement manufacturing plants are at present natural gas operated with noticeable advantages.

Of a great significance is the methanisation of the big basin kilns for glass production by the S. A. Vetrocoke at Marghera (Venice). Kilns have a capacity of 1,200 tons of glass with a glass yield of 80 ÷ 85 tons per day.

Since last year natural gas combustion has also been used in the Murano glass and crystalworks for the manufacture of the valued products known all over the world.

Other fields in which methanisation is being applied are the ceramic furnaces, the brick furnaces and the limekilns.

Significant is the transformation of the big limekilns of the S. Marco Company in Marghera (Venice) which are 3.20 m in diameter and 20 m high with a yield each of 60 tons of lime per day.

Investigations are at present being carried on to substitute coke by natural gas in the reduction of iron ores and the use of internal-combustion engines and turbines fed directly with natural gas is also being developed.

In each field the solutions worked out by Italian technicians and manufacturers, have resulted in very high efficiency, technologically better products, the reduction of operation time and in correspondingly notable savings in manual labour and in heat consumption.

Natural gas as a raw material for the chemical industry.

Many are the advantages when dealing with the natural gas utilisation in the chemical industry. Gases produced by solid fuels are always contaminated with inorganic substances and sulphur, and their use involves an expensive purification process, which sometimes represents a great difficulty for the chemical utilisation of such gaseous fuels; on the other hand natural gas and particularly Italian natural gas, the main components of which are carbon and hydrogen, is a pure gas which is particularly apt for the carrying out of the main chemical synthesis.

Although investigations and realizations on the catalytic conversion of natural gas into carbon oxide and hydrogen were first carried out in Germany, dealing with methane prepared via coal gas, the first significant plants for natural gas cracking (preparation of hydrogen from natural gas and from hydrocarbons) were set up in the Standard Oil Co. petroleum refineries at Baywai and Baton Rouge (USA 1920-1931), the former starting from a petroleum cracking gas and the latter from natural gas. Soon after and also in the refinery field (1930-1938) the plants of Permic (Netherlands), Abadan (Iran), Aruba (Dutch East Indies) besides some minor American plants were set up. In the same period in Italy were built for hydrogen production from natural gas the huge ANIC plants in Bari and in Livorno with a total yield capacity rising to over 500,000 cu. m. of hydrogen per day.

Worth remembering are the investigations and the pilot plants realized by the "Instituto Sperimentale dei Combustibili" in Milan, representing the first investigation using a catalyst for the oxidation of methane, not only by carbon dioxide and steam processing but also by oxygen and air.

The investigations of cracking reactions have led to the perfection and choice of the most economical plants and processes in order to obtain carbon oxide and hydrogen; all of these processes require thermal power for their running.

The various processes differ one from the other only in the way in which this thermal power is supplied.

It is possible to split the methane molecule either with chemical reagents at high or low temperatures or break it more or less gradually with heat only.

Oxygen is the most frequently used reagent; this oxygen is to be considered as a chemical reacting substance not to be confused with the oxygen required for thermic power production.

In suitable conditions the burning of methane with a quantity of oxygen insufficient for the total combustion, leads to the formation of a gas which is rich in carbon oxide and hydrogen. This incomplete combustion is performed in different ways: at present in Italy it is performed on an industrial scale and in foreign countries Italian proceedings are being adopted in presence or not of catalysts and in presence or not of steam.

This operation has now been perfected in all respects although it is not so simple as it seems when high yields and pure gases, i.e. without lampblack, are required.

For the production of synthesis gas from methane another largely employed reagent is steam — especially in America.

From the methane cracking a mixture of carbon oxide and hydrogen in different proportions according to the process used, is obtained.

From 1 normal cu.m. of methane and 0.65 normal cu.m. of oxygen about 2.7 normal cu.m. of carbon oxide and hydrogen are produced in the ratio 1 : 2. This mixture is used for various purposes, mainly for hydrocarbon synthesis and thus for the preparation of gasoline and lubeoils, applying the Fischer-Tropsch process which yields a range of hydrocarbons employable in internal combustion engines; by changing the catalyst, pressure and reaction temperature and by regulating the ratio of carbon oxide to hydrogen within definite limits it is possible to modify the constitution and the characteristics of the synthetic products.

From such a mixture it is also possible to obtain methylic alcohol, a fundamental substance for synthetic resins manufacturing, and higher alcohols required for the manufacture of solvents and other derivatives.

From the products yielded by the methane cracking it is also possible to prepare others among which acetylene is one of the most significant. Under suitable conditions acetylene production from methane should de taken into consideration in view of the economical way in which this product can be prepared.

Acetylene derivatives are acetaldehyde and acetone for the cellulose acetate rayon manufacturing, and vinyl chloride which after polimerization is inorganic and organic acid proof and is used for lining of containers and tube manufacturing and recently also for new textile fibers manufacturing.

Also to be mentioned is the great significance of acetylene during the II World War for the synthetic rubber production.

From the mixture of carbon oxide and hydrogen it is possible to obtain hydrogen of sufficient purity for ammonia production which holds a preeminent position in world economy. In effect from ammonia it is simple to prepare nitric acid for the preparation of nitrates and consequently for the production of nitrogen fertilizers.

The Italian chemical industry has increased its capacity in the production of ammonia via methane. The "Società Montecatini" in particular prepares ammonia in its Novara plant using two synthesis towers,

each having a capacity of 140 tons of ammonia and 110 tons of high pressure steam obtained from the reaction heat. The Società Montecatini is also running in Ferrara a big plant which yields 280 tons of ammonia per day via methane. Another plant of lower capacity is nearly completed for the Vetrocoke at Marghera.

The Società Edison is building a big plant for the acetylene and ammonia production via natural gas at Marghera.

Hydrogen production via methane yields as a byproduct a large amount of highly concentrated carbon dioxide.

This byproduct is being processed by Montecatini's for the production of 180 tons urea per day mostly used as a fertilizer.

The rights to use Montecatini's process for urea manufacturing have been granted to M. V. Kellogg of New York.

Methane reacts directly with other compounds as for example chlorine.

The reaction furnishes a mixture of four products more or less chlorinat-d from methyl chloride to carbon tetrachloride. It is possible to vary with.. wide limits the ratio of the different components of this mixture by changing the performance characteristics. A variation of this process, again starting from methane and chlorine, also results in the production of tetrachloroetilene, a chemical compound formerly obtained via acetylene. Italian processes of this kind have also been introduced into America by the Allied Chemical and Dye.

Methane reacts with ammonia to yield hydrocianic acid; also in this case the reaction, which is endothermic, is carried on by supplying the required heat by means of incomplete internal combustion in the batch or else by supplying heat by transfer. Also for the hydrocianic acid production via methane, for which a bright future is forecast, Italian processes are being applied.

As stated the chemical utilisation of natural gas always yields not final products but intermediates the most significant of which is synthesis gas; obviously these intermediates are used in already known cycles of operation by which finished products are obtained.

In comparison with other countries in which natural gas is available in significant quantities, Italy uses the highest percentage of its gas for the chemical industry.

In Italy the nitrogen fertilizer production via natural gas has grown side by side with the production from coke-oven gas, to which it is now almost equal in importance.

Other significant compounds such as methanol; chlorinated derivatives and hydrocianic acid are at present manufactures in Italy via natural gas up to the capacity required.

With regard to acetylene, the new fertilizer plants via natural gas have been set up in such a way as to allow the production of the whole amount required and even more.

The Italian consumption of natural gas as a chemical raw material may be at present envalued at around 200,000,000 normal cu. m. per year: this figure increases to 250,000,000 if the consumption for steam production required in chemical operations is considered. In Italy natural gas consumption for chemical utilisation is about 12% of the total, this is a high percentage which may be explained by the that in Italy the use of methane has been developed more rapidly in the chemical than in the thermic and power industries.

The contribution of Italian investigators and technicians towards solving the problems connected with natural gas.

The wide and complex problems presented by natural gas, which concern, besides its utilisation, the research, the well drilling, exploitation and distribution, have been brilliantly solved by Italian investigators and technicians.

As far as the recovery of natural gas is concerned only field engineering problems are involved such as the following: an exact knowledge of the physic-petrographic characteristics of the rock containers and of their extent, the proper spacing of wells and the methods and performance of their drilling, the circulation of mud, the lining and cementing of the wells, the recovery of hydrocarbons, the control of eruptive wells, the gas lift etc.

The solving of all these problems is due to the ability of the AGIP, and to the engineers of the Corpo delle Miniere and particularly to Agip Mineraria technicians who make use of modern and well equipped laboratories.

A noticeable contribution has been given by the Instituto Sperimentale per i Combustibili of the Milan Politechnic which has carried on investigations on natural gas since the time when the natural gas recovery was negligible.

The distribution of natural gas raised another range of complex problems, involving the calculation and the sorting of pressures and the most economical diameters for gas pipe-lines, and the choice of linings for pipes that are to be laid underground.

One of the aspects to which at present more attention is paid is the protection of pipes from dispersed currents. This problem has a particular significance in regard to the safe running of gas pipe-lines, as gas escaping from the pipes can have grave consequences for the inhabitants of the localities where they are laid.

Another side of the problems has been carefully investigated and it concerns the transformation of combustion plants now using other kinds of fuels; this transformation is performed in such a way as to achieve the highest efficency with the lowest costs and in the safest conditions. This side of the problem has been solved by the National Association for the

Control of Combustion to which the Government has allotted the task [illegible] the most economical and safest utilisation of fuels. The Technical Council of this Association examines the design of all new thermic plants and the designs for the transformation of the existing ones.

The aproval it given is necessary with recommendations and specifications for improving the plant.

After the new plants have been set up or the transformation has been completed, a control is exercised by competent engineers to ascertain that recommendations or specifications suggested have been applied.

The National Association for the Control of Combustion also provides for propaganda and specialist teaching in the particular fields of economical utilisation, of fuels, and safe usage of the pressure equipment.

Also the utilisation of natural gas in the chemical field the particular aspects of which have already been discussed, has been and continues to be the aim of practical investigations and research, which involve all the most important fields from the industrial point of view of our country. Scientific activity is directed towards the improvement of the operating cycles already performed in the different plants and the pointing out of new possibilities for industry.

I shall quote the "Donegani Institute of Chemistry" of the Società Montecatini equipped with the most modern and improved means of research.

From this short review it can be concluded that the Italian entry in the fuel gas utilisation field in the thermic, power and chemical fields has been really quick and notable, and it is also possible to forecast confidently that in the future new noticeable advances will be made owing to the present large availability of natural gas and to the bright pospects of new and important discoveries in the future.

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Summary

This report deals with the development attained in Italy by the utilisation of gaseous fuels and particularly by the utilisation of natural gas which represents a new powerful national source of raw materials.

The introduction is a short review of the Italian power situation; special evidence is given to the production of gases by distillation and gasification using foreign and national fuels, to meet the domestic requirements and those of the various technologies including the synthesis industry. The report investigates Italy's present production and utilisation of natural gas and the leading principles on utilisation of natural gas as a fuel in industrial furnaces, in steam generators for heating purposes and for electric power generation are examined. In addition some of the latest and most significant applications are pointed out.

The quick growth of the Italian chemical industry is also dealt with pointing out that this industry already uses a large amount of natural gas for the production of synthesis gas, which is necessary for the manufacture of nitrogen fertilizers and of methyl alcohol. The report forecasts the production of acetylene and its derivatives and the building of chemical compounds.

In addition the Author points out the Italian investigators and technicians contribution towards solving the problems connected with natural gas research, exploitation, distribution and utilisation.

Résumé

Ce rapport a pour objet le développement en Italie de l'utilisation des gaz combustibles et en particulier du gaz méthane naturel qui constitue une nouvelle ressource nationale.

Après un avant-propos qui donne un aperçu rapide sur la situation énergetique italienne et met l'accent sur la production du gaz de distillation et gazification à l'aide des combustibles d'importation et nationaux pour faire face aux nécéssités domestiques, aux nombreuses technologies, et particulièrment aux industries de synthèse, ce rapport expose la situation actuelle de la production et de l'emploi du gaz naturel en Italie

et donne des précisions sur l'emploi de ce gaz en tant que combustible [illegible] dans les générateurs de vapeur, soit pour le chauffage, soit pour la production d'énergie életrique.

Ce rapport expose en outre le développement rapide de l'industrie chimique italienne qui utilise déjà sur une très large échelle le gaz méthane naturel pour la production du gaz de synthèse employé pour la fabrication des engrais et de l'alcool méthylique et signale aussi le programme pour la production de l'acétylène et de ses derivés et d'autres produits chimiques speciaux.

Enfin ce rapport souligne la contribution donnée par les savants et les techniciens italiens à la solution des problèmes touchant la recherche, la cultivation, la distribution et l'utilisation du gaz méthane naturel.

Resumo

A presente monografia tem por objeto o desenvolvimento, na Itália, do emprêgo dos gases combustiveis e, em particular, do gás metano natural que constitui um novo recurso nacional.

Depois de um prefácio que dá um sumário sôbre a situação energética italiana e acentua a produção do gás de distilação e gaseificação por meio de combustiveis de importação e nacionais para fazer face às necessidades domésticas, às numerosas tecnologias e, em particular, às indústrias de sintese, essa monografia expõe a situação atual da produção e do emprêgo do gás natural na Itália e fornece detalhes sôbre o emprêgo dêsse gás como combustivel nos fornos industriais, nas caldeiras de vapor, seja para o aquecimento, seja para a produção de energia elétrica.

Além disso a monografia expõe o rápido desenvolvimento da indústria quimica italiana que já está utilizando, em largu escala, o gás metano natural para a produção do gás de sintese empregado na fabricação de adubos e de álcool metilico e nota, também, o programa para a [illegible]odução do acetileno e seus derivados e outros produtos quimicos especiais.

Finalmente a monografia sublinha a contribuição dada pelos sábios e técnicos italianos à so[illegible]ão dos problemas relativos à pesquisa, ao cultivo, à distribuição e à utilização do gás metano natural.

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ANDRIANOV (V.N.)
SAZONOV (N.A.)
Russia

UTILIZATION OF WIND ENERGY FOR THE ELECTRIFICATION OF AGRICULTURE IN THE U. S. S. R.

By V. N. ANDRIANOV

and. N. A. SAZONOV

RUSSIAN NATIONAL COMMITTEE

1. POTENTIAL RESOURCES

The electrification of agriculture in the U.S.S.R. is being effected on the basis of utilizing local power resources.

Wind energy may be listed as a local power resource. Being universally available and constantly renewed, wind energy actually possesses inexhaustible potential as a power resource.

A method roughly estimating the potential of wind energy resources that might be utilized by modern technology has been suggested by a Russian scientist, Professor N. V. Krassovsky. By arranging wind-turbines on the ground in chess-board order spacing them at intervals fifteen times as large as the wind-wheel diameter, it is possible to obtain an annual quantity of electric power for every square kilometer of surface area as given in table 1.

TABLE 1

Average annual wind velocity in m sec	3	4	5	6	7	8	9	10
Installed capacity of wind generators per sq km in KW	100	230	440	730	1210	1900	2720	3950
Annual output of electric power generated from 1 sq km, in thousands of KWh	200	480	900	1580	2600	3850	5180	7100

[illegible] with its vast territory, the potential of wind energy constitutes over 10 billion kilowatts with an average annual energy output of 18,000 billion kilowatt-hours.

2. PRINCIPLES OF UTILIZATION

Wind turbines have been used for driving mills in Russia for centuries. About 200,000 wooden windmills were built by peasants. The average capacity of these mills usually constituted only 5 HP, but there were also larger, 15 - 20 HP windmills with a wind wheel diameter of 20 - 24 meters.

The works of the well-known Russian scientist, N. E. Zhukovsky, the founder of modern aerodynamics, offered new possibilities for production of modern metal structures for wind-turbines. Manufactured metal wind-turbines and mechanically or electrically driven motors have gradually forced out the obsolete wooden types of windmills.

Wind-turbine installations as a source of energy supply for highly mechanized agricultural processes, typical of farming in the USSR today, are limited by the instability of their generated power.

As a result of many years of experience in the use of wind-turbines, certain methods of utilizing wind energy can be recommended for agriculture in the USSR, where planned electrification is being extensively carried out. These recommendations are as follows:

a) It is expedient to run high-speed small-sized wind-turbines in low-capacity wind installations designed for charging storage batteries and lighting individual houses in remote and sparsely populated districts where the average annual wind velocity is more than 4 meters per second.

b) Medium-sized high-speed and low-speed wind-turbines are recommended for operation in districts where the average annual wind velocity is more than 4 meters per second for running pumping stations that supply water to settlements and cattle-ranches and also for irrigating vegetable gardens and draining plots of land. Wind installations should have reserve motors and water storing reservoirs for periods of calm.

c) Large-sized high-speed wind-turbines are found to be expedient for wind-electric stations in districts where the average annual wind velocity is more than 5 meters per second.

3. TYPES AND SIZES OF WIND-TURBINES

A system of types and sizes of manufactured metal wind-turbines was developed in the USSR under the guidance of academician A. V. Winter. This system includes the following types of wind-turbines that are used in the Soviet Union:

a) high-speed wind-turbines with a wind-wheel 2 meters in diameter (D-2) for low-capacity wind-electric stations,

b) low-speed wind-turbines with wind-wheel diameters of 5 and 8 meters (D-5 and D-8) for pumping stations,

c) high-speed wind-turbines with wind-wheel diameters of 12 and 18 meters (D-12 and D-18) for d.c. and a.c. stations.

I. LOW-CAPACITY WIND-POWER INSTALLATIONS

A wind-power installation with a high-speed wind-turbine, D-2, is designed for charging storage batteries and supplying light to individual houses remotely located from settlements.

Technical characteristics of the D-2 wind-turbine are as follows:

1.	Wind-wheel diameter	2 m
2.	Number of blades	2
3.	Wind-wheel speed	280 600 r.p.m.
4.	Wind velocity necessary for starting	3.8 m/sec.
5.	Means of regulation -- centrifugal adjustment	
6.	Power developed by electric generator at a wind velocity of 8 m/sec.	100 w
7.	Total weight of turbine and generator	50 kg

A specially designed three-phase alternating current synchronous machine located in the head of the wind-turbine with permanent magnets as a source of excitation is used as a generator. The three-phase current is rectified by a selenium rectifier which also blocks current of the storage battery from the generator, thus simplifying the electrical scheme. The annual power output with an average annual wind velocity of 5 m/sec. is 250 kWh.

A wind-power installation equipped with a high-speed wind-turbine, D-12, is designed to supply direct current for lighting small remote settlements.

Technical characteristics of the installation are as follows:

1.	Wind-wheel diameter	12 m
2.	Number of blades	3
3.	Wind-wheel speed	60 r.p.m.
4.	Wind velocity necessary for starting	4.5 m/sec.
5.	Means of regulation -- centrifugal adjustment with stabilizers	
6.	Speed fluctuation	± 5%
7.	Power developed by generator at a wind velocity of 8 m/sec.	8 kW
8.	Weight of wind-turbine	1500 kg
9.	Energy generated annually with an average annual wind velocity of 5 m/sec.	25,000 kWh

[illegible] INSTALLATIONS FOR WATER SUPPLY

Low-speed turbines (types D-5 and D-8) are generally used as a source of supply for pumping water from wells with plunger pumps. They are started and stopped from below by means of a hand winch. The turbine speed is adjusted by varying the angle made between the wind-wheel and the direction of the wind.

Technical data of the above mentioned types of turbines are given in table 2.

TABLE II

Type of wind turbine		D-5	D-8
Wind-wheel diameter	m	5	8
Number of blades		24	18
Speed of wind-wheel at a wind velocity of 8 m/sec	r.p.m.	40	25
Tower height	m	15	15.4
Wind velocity necessary for starting	m/sec.	3	3
Shaft power of wind-turbine at a wind velocity of 8 m/sec.	HP	2.5	6.5
Total weight	kg	2170	2650
Tower weight including vertical shaft and reducer	kg	1200	2500
Productiveness in raising water to a height of 10 m at a wind velocity of 8 m/sec.	m^3/hr.	10	30
Energy generated annually at the wind-turbine shaft with an average annual wind velocity of 4 m/sec	HP.hr.	4.9	12.5
" " " " 5 m/sec.	" "	7.8	20.0

6. WIND-ELECTRIC STATIONS

At the present two designs of high-speed wind-turbines with a wind-wheel diameter of 18 meters and a rating of 30-50 kilowatts, suitable for running an electric generator have been developed. One of them is a stabilized wind-turbine with an inertia-aerodynamic adjusting system (D-18) proposed by G. H. Sabinin and N. V. Krassovsky; the other is an aerodynamic self-adjusting wind-turbine (I-D-18) proposed by A. G. Vetchinkin and A. G. Ufimtzev. Design and construction data of a wind power unit rated at 100-140 kilowatts with a wind-wheel diameter of 30 m (D-30) that operated in the Crimea up to 1941 is available.

For purposes of rural electrification, wind-electric stations are expedient when operating jointly with larger electric stations that utilize local "non-wind" power resources. Wind-electric stations compensate for the shortage of basic kinds of resources such as water and fuel

Small wind-electric stations installed for joint operation with small power stations to economize fuel of the latter are an important item in the utilization of wind energy.

Combining wind-electric stations with hydro-electric and thermo-electric stations into one power system gives the simplest solution to the problem of storing wind energy. It eliminates the basic deficiencies in the operation of wind-turbines, namely, – unsteadiness and irregularity of operation.

The capacity of wind and "non-wind" stations can vary within wide limits beginning with practically equal capacity of the two and ending in the operation of a wind station in a system of incomparably greater capacity.

Parallel operation in a system should be considered as a basic method of operation for wind-electric stations.

The capacity of wind-electric stations operating in parallel in a system should be matched by the capacity of the other stations.

Individual wind-electric stations with a small energy reserve, or even without one, will be extensively introduced in windy areas (that is, in areas with favourable wind conditions) that are underdeveloped from an economic stand point.

7. AN INDEPENDENTLY OPERATING WIND-ELECTRIC STATION

Independent operation of an a.c. wind-electric station, even when thermal energy is available, still lacks uniform energy supply.

Operation of a wind unit at practically constant speed (frequency) for varying wind velocities is obtained by equalizing the power developed by the wind-turbine to that of the load by automatically switching in and out parts of the load. The impulse for switching is given by a change in frequency due to a disruption of the balance between available and output power of the wind-turbine. The influence of load fluctuation on the voltage is eliminated by means of compounding devices. For an independently operating wind-electric station, the reduction of power fluctuation for wind velocity changes of a short duration (micro-pulsations) is of importance.

An "inertia accumulator" originally introduced by A. G. Ufimtzev and applied on wind-turbines TD-18 appears to be effective. The "inertia accumulator" is a massive rapidly rotating disc, that is solidly connected to the generator shaft and also connected to the wind-turbine shaft through a slip coupling. The "inertia accumulator" compensates for the most frequent lapses in wind-turbine power that according to experimental data never exceed 1 – 10 – 30 sec.

The wind-electric station TD-18 equipped with an "inertia accumulator" may provide electric energy for labour-consuming farm processes

...schedules such as water supply, fodder-preparation, sheep shearing and others. At nigth, when the basic load is low, the output of the wind unit should be used for heating homes and water.

8. PARALLEL OPERATION OF WIND AND "NON WIND" ELECTRIC STATIONS

The design of units having wind-turbines that operate with a varying number of modules and a constant speed is a sound trend in the development of medium sized wind-power installations (up to 1000 KW), especially for those designed for agricultural loads. Such practice leads to the use of standard a.c. machines.

The capacity of larger wind-power u... should not be raised, but their number should be increased. This avoids certain construction difficulties inherent to large wind-power units and increases the stability of the electric system.

Parallel operation of wind-power units D-18 and D-30 in an electric system was tested in the USSR both with an induction and a synchronous generator. For an induction generator wind-power installation operating in a rural power system, the regulating system should counteract fluctuations in frequency during normal operation as well as during switching. The design of a regulating system on the centrifugal principle is a rather difficult task that also complicates the system.

It is important to note that induction generators weaken the operation of a system lowering its adaptability. When extensively utilizing wind energy for electrification purpose, the application of synchronous generators in wind-power installations appears to be a proper solution. This does not exclude the possibility of using induction generators. Their application, however, should be limited as a whole to a system of incomparably greater capacity.

For parallel operation through a synchronous generator, conditions of stable equilibrium are observed on the right as well as on the left side of the torque curve of a wind-turbine. In the second case, the self-adjusting characteristics of the wind-turbine become more pronounced. This phenomenon was first observed by a Russian scientist, G. H. Sabinin, in 1931. This is found to be favourable for the stability of a wind-power unit when passing to a new load and also from the standpoint of overloading at high wind velocities.

For a definite range on the left side of the curve, considerations of reducing the effect of wind gusts are fully consitent with the problem of obtaining the greatest possible annual output. In Germany, a similar statement made only in 1943, appeared in the form of a patent claim as a method of running a wind-power synchronous generator in parallel with a constant frequency system.

The most important problems of wind-electric stations, equipped with synchronous generators parallelly operating in a system are as follows:

1. synchronization at the moment of switching.
2. adjustment for limiting capacity of the wind-power unit at a wind velocity exceeding its rated value.
3. operation in a system of comparable capacity.

When synchronization takes place, owing to the continuous pulsation of wind-energy on the generator shaft, a varying excess torque Mex. causing rather sharp fluctuations of the angular velocity of the wind-power unit is inavoidable.

Synchronization of a wind-electric station is performed by starting the wind-turbine with lowered aerodynamic characteristics and applying the method of self-synchronization.

The allowable speed of frequency change of the generator at the moment of synchronization is equal to

$$\frac{d\,f\,gen.}{d\,t} = 50\,\frac{Mex.}{C\,gen.} \qquad (1)$$

This value is small because the inertia constant of the wind-power unit, C gen., has a relatively large value. To avoid switching the generator into the system with intolerable values of the acceleration, it is advisable to make the switching automatic by using self-synchronizers such as frequency difference induction type relays.

When the wind velocity exceeds its rated value, which is observed during strong winds and also when the average velocity of the air current is lower than its rated value, it is necessary to limit the capacity of the wind-power unit for stability as the unit is connected to a system, and also for the prevention of overloads. In practice, this makes continuous regulation of the blades during operation absolutely necessary. An aerodynamic stabilized regulation system developed by Russian scientists, G. H. Sabinin and N. V. Krassovsky, and applied in the USSR for the wind-turbines D-18 and D-30, makes regulation of wind-electric stations operating in parallel practicable from the standpoint of stability as well as overload. In general, regulation for parallel operation should be based on the torque principle; however, when operating with a station of the same capacity, regulation may be effected on the centrifugal principle.

Much less work for regulation is required in acting on the stabilizers (aerodynamic servomotors) than in acting directly on the blades (direct regulation). This simplifies the job of designing a governor reacting to wind changes that affects the angle setting of the stabilizers.

The governor of an aerodynamic self-adjusting wind-turbine, I-D-18, may perform the function of protecting the wind-turbine against overloads.

The reliability of the regulating system of a wind-turbine in a unit operating in parallel cannot be estimated when the above mentioned method of regulation, which has greater inertia and is less accurate, is used. Tests of governor operation are required.

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Other methods achieving regulation, such as those repeatedly mentioned in scientific literature abroad (e.g. the pitch control method, proposed by Honnel, or the flap control method proposed by M. Kloss) might require a considerably longer time than may be permissible from stability considerations and also because of overloads that may occur with an increase in wind velocity.

The limitation of the input torque transmitted to the generator shaft can also be obtained by means of a coupling inserted between the synchronous generator and the wind-wheel. In stabilized wind-turbines the application of slip couplings makes inertia-regulation possible. The use of a slip coupling on aerodynamic self-adjusting wind-turbines of I-D-18 type will protect the wind-turbine against overloads for imperfect regulation. The type of coupling used is determined by the operating time of the coupling while slipping. For rural wind-electric stations (especially medium-sized stations), electromagnetic couplings with a bare armature (without a winding), seem to be the most promising.

9. OPERATION IN A SYSTEM OF COMPARABLE CAPACITY

When operating in a system of comparable capacity, power pulsation in a wind-electric station equipped with a torque limiting device will occur within the range limited by the regulator. Power pulsation will also occur with an increase of power above the limit set by the regulator because of its insensitivity.

Up to the present, turbine regulating devices in many rural hydro-electric stations, if they exist at all, react slowly and lack sufficient sensitivity to respond to power pulsation from wind gusts.

Ability of the system to attain a new equilibrium is estimated by its self-regulating property determined by the path of torque characteristics of prime movers and by system loads.

An analytical investigation of an electric system consisting of a wind-electric station and a "non-wind" electric station showed that transients in the system take place without practically any circulation of exchange power for power pulsation of the wind-electric station. This fact is of importance. Otherwise, slipping out of synchronism and sharp fluctuation of the system voltage should be feared. A change in angular velocity of the system is characteristic, irrespective of the amount of pulsation of the wind station and relative generator capacities of the wind and "non-wind" stations that can, in the limit, even be equal. The angular velocity of the new state of the system is expressed as follows:

$$\omega_K = \frac{M_{0}\beta + M_{w1} + M_{ex}\omega_1}{A\beta + A_c} \qquad (2)$$

where: M_{w1} - torque, produced by the wind-turbine before the transient

$M_{ex\ wt}$ — excess torque of the wind-turbine, arising in the system because of a change in wind velocity.

The terms — M_{ogt}, A_{β} and A_c are explained by the following definitions:

$M_{ogt} = \omega A_{\beta}$ — prime mover torque characteristic of a "non-wind" electric station at a definite discharge-opening (β) of the regulating device

A_{ca} — load torque.

Load redistribution between a wind and a "non-wind" electric station at a variable wind strength is derived from characteristics showing the dependence of the wind unit speed (in r.p.m.) on the wind velocity $n = f(v)$ at a given load torque M = const., and on static characteristics of the prime mover of a "non-wind" station as shown on fig. 1.

A slip coupling, inserted between the wind turbine and the generator that prevents the wind unit from acting as a ventilator with a decrease in wind strength, is a necessary design feature of the kinematic scheme of a wind-power unit.

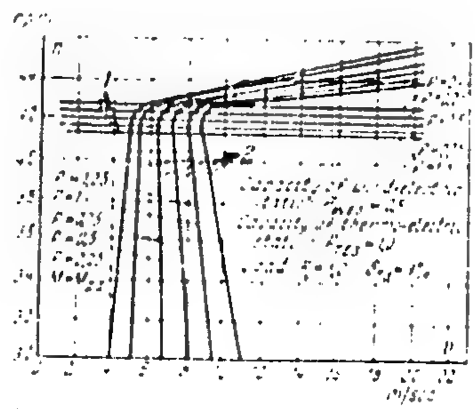

Fig. 1 — 1. Regulation characteristics of the thermo-electric station. 2. Regulation characteristics of the wind-electric station.

The allowable division of system capacity between a hydro- and wind-electric station is an important problem that should be investigated. The role of wind-electric stations in a system is basically determined by unevenness of system operation due to fluctuations of their power. An equation determining the allowable power pulsation of wind-electric stations depends on allowable frequency variation of the system and on parameters of the hydro-unit with basic capacity of the wind-electric station available. It can be expressed as follows:

$$K_2 = \frac{\omega_r}{\omega_r}\left|\frac{\beta-\beta_0}{\alpha\beta(1-\beta_0)}\left[1-\frac{\omega_r}{\omega_t}\left(1+\alpha\beta-\frac{\omega_r}{\omega_t}\right)\right] + K_1\frac{\omega_r}{\omega_t}\right| - \frac{\beta-\beta_0}{1-\beta_0}\cdot\frac{1+\alpha\beta}{\alpha\beta} - K_1$$

where K_1 — basic capacity provided by wind-electric stations

K_2 — pulsating capacity of wind-electric stations

β and β_0 — openings in the guiding device of the hydro-turbine for the general case and for idle running, respectively

$\alpha\beta$ — relative number of revolutions of a hydro-turbine for starting without load

ω_t, ω_r and ω_r — lowest, highest and rated speed of a hydro-unit, respectively.

A curve showing the role of wind-electric station capacity can be plotted on the basis of equation (3). This capacity is referred to load capacity of the system, C_0, and depends on the extent of power pulsation of wind-power stations expressed in terms of the relation

$$\frac{K_2}{K_1+K_2}$$ (See Fig. 2)

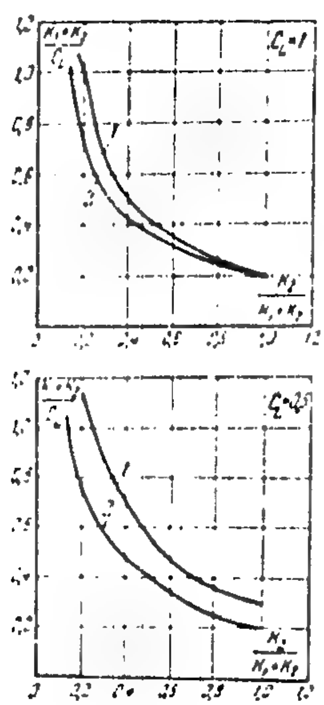

Fig. 2 — 1,2 — Curves of two types of wind turbines.

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Combining wind-electric stations into groups and increasing the rotating mass of wind-turbines are effective means of reducing the pulsating power value of wind-electric stations. This increases their role in electric systems.

The transient time constant may be increased by equalizing the capacity of a hydro-electric and a wind-electric station at a value higher than the limit established by allowable system fluctuation. This is accomplished by reducing the capacity of the hydro-electric station and increasing the number or size of wind-electric stations.

It is not excluded that under such conditions regulators of prime-movers in "non-wind" stations could restrict a temporary unevenness of running to allowable limits even when the final speed of the system differs from the top allowable one only by the speed necessary for self alignment.

10. EFFECTIVENESS OF WIND-ELECTRIC STATION UTILIZATION

The amount of industrial potential of wind-electric stations can be determined only from specific conditions of projected installations. Only afterwards can the question be raised of estimating the power effect obtained by connecting wind-electric stations into a system.

The necessity of considering fluctuations in system operation was mentioned above. Besides, when equalizing installed capacity of wind-electric stations to maximum system loads, concurrent with an increase of the absolute value of wind energy fed into the system, Ag, a part of this energy, which could not be utilized because of the divergence between load charts and wind currents, will also increase. In this, the potentiality AB presented by the installed capacity of the wind-power unit is considered available.

The value of the power factor $K = \frac{Ag}{AB}$ preferred for the specific case of projecting a wind-electric power system, will depend upon the amount of energy obtained in addition from wind-electric stations considering the increase of wind-power cost with a decrease in K.

The participation of wind-electric stations in a system will result in water accumulation when running in parallel with a hydro-plant, or in fuel economy when operating with a thermo-electric station. This effect may be estimated by the wind-power value introduced into the system Ag, considering that the "non wind" power units will operate under conditions in which the specific consumption of utilized resources (e.g. water and fuel) will increase. For the case of operation in parallel with a hydro-electric station, the losses occurring while consuming the energy reserve contained in the saved water should be additionally considered. This

depends on the load characteristic of the hydro-station utilizing the economized water reserve. The ratio of excess power on the buses of the hydro-electric station to the power directly fed by wind-electric stations into the system is called power efficiency $Ke = \frac{Ae}{Ag}$ and depends mainly upon the type of hydro-turbine.

It has already been mentioned that the indices characterizing the effectiveness of connecting wind-electric stations with "non-wind" electric stations, will in many respects depend upon specific conditions of such a combination. The true values of those indices will be determined in the actual course of projecting wind-electric stations, which up to now is insufficient. Nevertheless, preliminary work carried out for this purpose allows one to forecast a general estimation of the effect of connecting wind-electric stations with both hydro-electric and thermo-electric stations:

1. For districts with an average annual wind velocity of $V_{av. an.} = 5$ m sec., connecting to a hydro-electric station in level country a group of wind electric stations with a capacity of 80% of that of the hydro-eletric station permits an increase of consumption of about 30%. In this case, a water reservoir with a capacity of 2 to 4 weeks of regulated dischage should be available at the hydro-station.

2. An increase of capacity for additional consumers connected to a hydro-electric station as a result of the operation of a wind unit might be possible by providing high-speed or high-frequency regulators to the prime movers of the hydro-electric station. At the same time, the value of regulated discharge should also increase approximately in proportion to the increase in capacity of additional consumers.

   An increase in capacity of additional consumers can also be obtained by equipping wind-electric stations with inertia accumulators (fly-wheels), which would reduce their pulsating power.

3. A thermo-electric and a wind-electric station of practically equal capacity operating in parallel economizes fuel in districts with average annual wind velocities

$$V_{av. an.} = 4.5 - 5.5 \text{ m/sec. by an amount:}$$

$$\Delta Q = 30 - 50\%.$$

   If it is possible to switch out the thermo-electric station during periods of steady strong winds, fuel economy is increased approximately by 5 per cent for every 10 per cent of general operating time when the wind-electric station operates alone.

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SUMMARY

The potential resources of wind energy have been defined and the principles of its utilization examined. Types and sizes of wind-turbines are determined. Low-capacity wind-electric installations and wind-power stations for water supply have been described. The problem of utilizing wind-electric stations in the electrification of agriculture is elaborated.

Parallel operation of wind stations in which synchronous generators are used with "non-wind" stations is proposed as a basic method. The capacity of these stations can vary within wide limits beginning with practically equal capacity of the two and ending in the operation of wind stations in a system of incomparably greater capacity.

The basic points of operating wind-electric stations in parallel in a system have been discussed viz. synchronization, limitation of wind-unit capacity from the standpoint of system stability and overload because of wind gusts, operation in a system of comparable capacity. The role of wind-electric stations in a system is shown in connection with pulsations in supplied energy. The significance of combining wind-electric stations into groups is given.

The effectiveness of utilizing wind energy for operating wind electric stations in a system of comparable capacity with hydro-electric and thermo-electric stations is described.

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CONFERENCIA MUNDIAL DA ENERGIA
WORLD POWER CONFERENCE

Titulo 6
Assunto 6.1

REUNIAO PARCIAL
SECTIONAL MEETING
Rio de Janeiro — 1954

IOSIFIAN (A.)
Russia

METHODS OF SUPPLYING ELECTRIC ENERGY TO AGRICULTURE IN SUB-TROPICAL AREAS

By A. IOSIFIAN

Professor of Electric Engineering, Doctor of Technical Sciences, Member of the Academy of Sciences of the Armenian S.S.R.

RUSSIAN NATIONAL COMMITTEE

Scientifically summarizing experience gained from the electrification of agricultural process makes it possible to determine the most expedient methods and techniques in electrifying tropical and sub-tropical areas.

These methods depend on the character and extent of electrification of agricultural processes as well as on the organizational structure of agriculture. The character and extent of electrification of agricultural processes are determined by geographical conditions in a given area.

Experience shows that a survey of agricultural possibilities in given areas of a country should be compiled in accordance with the geography and climate of the latter so as to most effectively and correctly utilize these natural factors in obtaining a maximum of agricultural produce at a minimum cost.

It is of interest to consider the following economic zones of agriculture from the point of view of obtaining a maximum of agricultural produce: zones of irrigated farming, of citrus and oil yielding crops, of technical crops, of vegetables and forages, of livestock-raising. Industrial centres and points where agricultural produce are being processed should be taken into consideration.

An economic division of zones in accordance with the kind of agricultural produce raised has an exceedingly important technical meaning in as much as it determines, fundamentally, the technology employed in agriculture, furnishing this technology with appropriate equipment, and establishing corresponding energy supply indexes.

The technology employed in agriculture, furnishing this technology with appropriate equipment and energy supply is directly dependent upon the organizational structure of agriculture. Rational application of

modern machines, proper methods of land cultivation, and rational utilization of natural potential (geography and climate) of any one area are determined by the existing organizational structure of agriculture.

On the basis of a thorough analysis of electrified agricultural processes in the U.S.S.R., it was established that electrification of the drives of all main stationary machinery coupled with use of electrical appliances for productional and domestic purposes constitute the principal phase of electrification. The following types of work and operations are being electrified: threshing, winnowing, irrigation, water supply, ensilage cutting, cotton-cake crushing, root washing, separation, ventilation, sawing, milking, gristing, metal and wood work, and refrigeration. In mountainous areas, in addition, electric energy is used to render proper temperature to soil in green- and hot-houses and to dry agricultural produce. In areas where cheap electricity is available, it is possible to plough and harvest grain crops by means of electric tractors and combines.

Electric energy requirements of agriculture in the U.S.S.R. are computed in the following manner:

a) A general plan is composed on a geographical basis locating the main points of energy consumption in agriculture. The specific agricultural processes depending on climate and soil conditions are indicated.

b) Norms per unit (*) and afterwards composite norms of installed consumer capacity in kW and energy consumption in kWh are worked out.

c) Tables of approximate daily, seasonal and annual electric energy consumption by agricultural consumers and maximum loads for each of the administrative agricultural regions are established.

d) An energy balance coordinating existing energy resources with energy demands of agricultural consumers is compiled.

In the majority of cases, norms per unit are the same for various economic zones. It is possible, for example, to establish a norm per unit as an average per person from averages of statistical data of public and domestic electric energy consumption in rural areas. This energy is expended on privately owned electrical appliances, radio, cinema, water supply of homes and illumination of homes, streets, public and cultural institutions, warehouses, bakeries etc. In sub-tropical areas of the U.S.S.R. such as Armenia and Georgia, this norm varies from 580 to 1100 kWh yearly per person.

It can be similarly shown that the energy expended in milling one hectare of grain varies from 16 to 25 kWh per hectare; and the energy expended in watering one hectare of land with a one meter rise varies from 13 to 18 kWh yearly.

Data of electric machine and tractor service stations in areas near large hydroelectric stations (particularly, in the area near the Dnieper

(*) A norm per unit is a norm per person or per unit of produce or per head of cattle etc.

hydroelectric station) indicate that electric tractors and combines are used for the following operations: ploughing, sowing, cultivating, etc. On the average, 15 to 50 kWh per hectare of land are consumed by electric tractors and combines with ratings of 35 to 15 kW for the above mentioned operations.

Average figures of annual electric energy consumption by livestock and poultry depending on the extent of electrification are as follows:

cows	215-550 kWh per head annually
swine	320-700 kWh per head annually
horses	54-111 kWh per head annually
sheep	2.7-3.5 kWh per head annually
chickens	3.5-6.5 kWh per head annually.

Installed capacity and energy consumption of related rural works such as windmills, peeling mills, churneries, work shops, saw mills, raw material processing plants, drying plants etc. usually are determined on the basis of average figures per unit of product. For example, 10 to 11 kWh are consumed for drying one ton of grain, and 15 to 18 kWh for one ton of cotton; 25 to 30 kWh are consumed by flour mills and peeling mills for each ton of product.

Norms per unit corresponding to the design and construction of machines and other equipment used in agriculture are necessary but not sufficient to determine energy requirements of agriculture as a whole and electric energy requirements in particular.

It is necessary to work out composite norms applicable to a given geographic and economic zone. A composite norm depends, fundamentally, on the organizational structure of agriculture in a given geographic zone. The organizational structure of agriculture determines the most expedient crop distribution for different types of land (e.g grains, technical, vegetables and other crops) and the extent of livestock development there. These organizational structures of agriculture also determine the technology employed in agriculture, the types of machines and agricultural implements used there and the capacity of power stations that are necessary to provide technological processes with the latest technique afforded by modern science.

The history of the development of agriculture in the U.S.S.R. shows that when individual farming constituted the main organizational structure of agriculture, construction of rural electric stations, mass inculcation of modern machines such as tractors, combines, cotton-pickers, hay-harvesters and others on a country-wide scale was impossible. These farms developed spontaneously and accidentally; they had a weak economy and consisted of small plots of land. This did not allow for the inculcation of modern technology. With the change from individual to cooperative farming involving 1,000 to 10,000 hectares of land, machine and tractor service stations were organized which, as national property,

provided cooperatives with the latest machine technology. This, also, permitted government planning for all of agriculture. All of this made possible:

a) application on a country-wide scale of the latest machine techniques afforded by modern science

b) planned mass production of various modern machines needed in the field, in cattle ranches and elsewhere in agriculture

c) establishment of composite norms of electric energy consumption in agriculture in accordance with geographic zones of the country.

Inculcation of modern techniques in agriculture is the principal measure that results in an increase of agricultural produce.

In 1953 in the U.S.S.R., 99.2% of all ploughing was done by tractors, 75% of all sowing was done by machines and over 60% of the grain crop was harvested by combines. 700,000 tractors of 15 different designs operating on the collective farms of the country resulted in the above mentioned extent of mechanization. The main types of tractors used are diesels with a power rating of 50 HP and more having attached, far reaching agricultural implements.

In several sections of the country such as the sub-tropical Krasnodar Region on the Black Sea with an area of 250,000 sq.km, geographical conditions permit a very high degree of mechanization, e.g. 100% of ploughing, 99.4% of harvesting of grain and sunflower crops, 90% of hay-making and 70% of storing forages.

Composite norms of electric and heat energy consumption in agriculture in the U.S.S.R. have as a base unit one hectare of cultivated land, in as much as this unit most clearly indicates the extent of mechanization and electrification of technological processes in agriculture taking into account particularities of different branches of agriculture.

By further taking into account cultural and domestic electric energy demands of the population as well as those of rural industry, a general composite production-al domestic norm per hectare of cultivated land can be established for every agricultural zone.

Electric energy consumption in the U.S.S.R. varies from 100 to 500 kWh annually per hectare of ploughed land depending on geography, climate, and mechanization. The installed capacity correspondingly varies from 0.1 to 0.6 kW per hectare.

Data of electrification of agriculture in southern sections of the U.S.S.R. show that composite norms are greatly influenced by the size of the farm. Some cooperative farms having up to 500 hectares of land have composite norms of 100 to 500 kWh annually per hectare. At the same time, farms having more than 5000 hectares of land have norms of 80 to 300 kWh annually per hectare.

The above mentioned norms are greatly exceeded by individual farms having several or even tens of hectares of land

Having established composite norms of energy supply for a given geographical area, means to meet energy demands will be analysed. First of all, all local energy resources characteristic of a given geographic area should be singled out, e.g. energy of large and small rivers, energy reserves of local types of fuel, wind and solar energy.

Rational utilization of local energy resources should be made the basis of energy supply for agricultural processes. Hence, it is necessary to comprise for each zone:

a) a scheme for the utilization of hydro resources of small rivers taking into account irrigation needs that indicates type, capacity and performance characteristics of hydroelectric stations.

b) a scheme for the utilization of local fuel resources (coal, peat, timber, solar energy, natural gas, etc.) that indicates the advisability of their utilization considering means of their transportation and transportation costs.

c) a scheme for the utilization of wind energy and the location of wind station installations indicating their type, power rating and performance characteristics.

d) a scheme for the utilization of electric energy of rural power stations, large power systems and stations, as well as power stations of sugar refineries and other rural factories located nearby.

The problem of rationally utilizing local energy resources is specific in its character and is solved only by economic considerations such as capital investment, operating costs, and technical characteristics of the type of energy used.

The most rational method for utilizing wind energy involves the construction of numerous stations for driving mechanisms that do not require constant power and speed of rotation. Gristing, operation of pumps for water supply and irrigation purposes, preparation of fodders are a few of the agricultural processes that can utilize wind energy.

The average power of wind energy in southern sections with an average annual velocity of 5 to 8 meters per sec. can reach 100 KW per sq.km.

The use of wind installations coupled with electric storage batteries and other types of energy storage equipment is also of interest.

In considering the problem of energy supply of tropical and subtropical areas, special attention should be given to solar energy stations because in these areas energy of solar radiation at sea level varies from 300 to 700 kilocalories per sq.meter per hour for 8 to 10 hours a day. This radiation noticeably increases for higher altitudes.

It might be economically and technically advantageous to connect agricultural loads to high voltage transmission lines of large power systems or to electric railway lines if the latter are at hand. The expediency of such a technical solution is determined fundamentally by the capital investment for the distribution substation and by the economically advantageous limit of the size of the electrified area. The expedient limits

of electrifying an agricultural area from large power systems is determined by economical calculations. The following items are put as a basis in these calculations, metal expenditure, initial investment, energy loss, perspective development of agriculture, determination of optimum capacity of rural sub-stations as compared with optimum capacity of rural power stations, evaluation of centralized and local energy supply for agricultural loads, determination of the optimum number of lines branching out from a sub-station.

Experience in energy supply of agricultural areas in the U.S.S.R. shows that utilization of local energy resources proves to be the most economical.

In working out schemes of energy supply from local (rural) power systems as well as from large power systems, it is necessary to consider that agriculture is a large consumer of heat energy. Energy balances of cattle ranches show that electric supply of drives of various mechanisms constitutes only 15÷20% of the total energy supply. The remainder is heat energy that is expended for steaming fodder, heating water, pasteurizing milk, heating buildings, etc. Thus, utilizing local energy resources and in particular solar energy in tropical and sub-tropical areas is of the greatest importance.

The determination of rational ways of mechanizing, electrifying and supplying agriculture with energy is a vital problem that confronts humanity in its struggle with nature for increasing the standard of living.

This calls upon all people of good will to mobilize all their strenghth to find as rational a solution to these problems as afforded by modern science and technology.

SUMMARY

This report defines the dependence of technology used for agricultural processes on the organizational structure of agriculture. A method is presented for determining composite norms of energy consumption applicable to various economic and geographic zones on the basis of norms per unit. A method of drawing up a plan for the development of electric energy supply of agriculture, taking into account local energy resources and composite norms of energy consumption, is proposed.

RESUMO

Essa monografia define a dependência da tecnologia empregada para processos agrícolas na estrutura de organização da agricultura. Apresenta um método determinando normas compostas do consumo de energia aplicável às várias zonas econômicas e geográficas na base de normas por unidade. Propõe um metodo para o levantamento de um plano para o desenvolvimento da aplicação da energia elétrica na agricultura, levando em conta as fontes de energia local e normas compostas do consumo de energia.

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CONFERENCIA MUNDIAL DA ENERGIA
WORLD POWER CONFERENCE

Titulo 1
Assunto 1 1

REUNIAO PARCIAL
SECTIONAL MEETING
Rio de Janeiro — 1954

YOSHIOKA (T.)
Japão

THE ELECTRIC POWER DEVELOPMENT PLAN OF JAPAN

By TOSHIO YOSHIOKA
Chief Engineer, Public Utilities Bureau, Ministry of International Trade and Industry

JAPANESE NATIONAL COMMITTEE

1. INTRODUCTION

In case of setting up an electric power industrial plan, it is necessary to predict the precise electric power demand of the future, however, as the construction of power generating station takes a long period of 3 to 5 years, at least, an estimation of the long period electric power demand of 5 years should be made. Moreover because of the fact that electricity is not only absolutely necessary for the livelihood of the general public as light, heat and power, but also that it has a wide demand in the field of metal industry and chemical industry as to be used as heat sources, and as a raw material, in case of estimating the power demand, it is necessary to ensure the forecast of the overall foresight of the industrial and economical aspects as a whole as well as the forecast of consumption level of the general public.

2. THE PRECEDING CONDITIONS FOR THE LONG PERIOD PLAN

Our country who has to feed a huge population increasing rapidly every year wriggling within the four islands which is narrow with nothing but a meagre resource, — in such a country, what economical scheme should be worked out for it's realization, so that our people who suffered from the life of poverty of the post war years, may be able to gradually raise her consumption level and at same time to attain the self support of her economics by balancing the international revenue and expenditure in the year 1957? For solving such problems, we have decided to set up the scheme with the following preceding conditions.

a. The political situation of the world is to continue approximately as it is now.

b. The present exchange rate (1 dollar — 360 yen) is to be maintained as it is now.

c. Based on the assumed population of 85,839 thousand for the year 1952, the population of the year 1957 is to be assumed as 91,358 thousand, which is 6.4% increase based on the recent trend of increase.

d. The consumption level per capital, against the actual result of the year 1952 (95.6% against the 1934 — 1936 year level) is to be assumed as 10% increase for the year 1957. This level corresponds to about 105% against the pre-war years level mentioned above.

2-1. The scheme of the economical activities for the year 1957

In accordance to the preceding conditions mentioned previously, the gist of the economical activities of our country set for the year 1957 is as follows.

Item		Unit	The actual result of the 1952 (A portion assumed)	Plan for the year 1957
Export		million dollars	1,168 (100)	1,570 (134)
Import		"	1,790 (100)	2,080 (116)
International Revenue and Expenditure	Received	"	2,158 (100)	2,288 (106)
	Payment	"	2,065 (100)	2,288 (111)
	Balance	"	93	0
The mining & industrial production index No.		1934-1936 (100)	139.4 (100)	170.0 (122.0)
The index number for agricultural, forestry and marine production		"	107.0 (100)	119.5 (111.7)

a. Regarding the foreign trade the target particulary was set for the improvement of the balance of international revenue and expenditure, through the normal trade. As a measure of cutting down the import of food and textile goods, we have considered to work out the impro-

vement of the extent of self support by furthering the plan of increasing the production of food and synthetic fibre as well as to decrease the import of machineries by the development of domestic machinery industry. Against the actual import result of 1 790 million dollars for the year 1952, 2080 million dollars of import, an increase of 16%, is expected for the year 1957.

b. Although the international revenue and expenditure is to be balanced temporarily in the year 1957, against the trade balance of excess import, this is due to the amount of temporary revenue taken into account other than that from trade such as due to the special demand in connection with the U. S. garrison in Japan therefore after, the year 1957, we have to endeavour to improve qualitatively in a further extent. Likewise, the reason the balance for the year 1952 shows excess in import is due to the large amount of special demand from the circles concerned with the U. S. garrison.

c. Regarding the export the present trade aspects of declining trend is to normalize after the year 1954, and for the time being, it is to be able to develop with the incremental rate of about 7 — 10% per year which is the average incremental rate of exports in the past. After furthering the investigation on the possibilities of export in regard to the respective classification of commodities, in the year 1957, we are to be able to export for the amount of 1 [illegible]70 million dollars. This corresponds to the expansion of 134% against that of the year 1952. Besides, the composition of the export commodities is changed as follows.

	Actual Record 1934-1936	Actual Record of 1951	Actual Record of 1952	1957 Plan
Textile	52.1%	47.0%	35.0	37%
Machinery	7.1	7.8	8.7	21
Metal	8.2	15.7	26.8	10
Others	32.6	29.5	29.5	32
Total	100	100	100	100

d. The production schedule of mining and industry is to be determined by the production amount of the items of the commodities required for the accomplishment of consumption level and the trade schedule as mentioned previously for the year 1957.

As for the result the index number of mining and industrial production, as given in table 1, is 170% setting the 1934-1936 average as the criterion and 22% increase against that of the year 1952. This level is somewhat lower than the pre-war maximum 178.8% (for the year 1944).

3. ELECTRIC POWER FIVE YEAR PLAN

3-1. Estimation of the Electric Power Demand

In case of determining the electric power service development plan the power demand to be set as the target, should be necessary and sufficient to attain the economical activities and the living standards of the year 1957 as previously mentioned.

We would like to explain briefly on the gists of the estimation of the electric power demand. We have decided to compute the total electric power demand including that of the electric power enterprises and the industrial captive power plant. The annual electric power energy, if classifying roughly, consists of industrial use and non-industrial use, however the computation of the demand is to be carried out mainly by the required electric energy per criterion amount (unit energy demand), and those which are impossible shall be judged by the trend of the past actual record and the index number of the target production.

a. The estimation of the demand for industry

The required electric power energy for the mining and industrial production plan given in Table 2 is determined mainly by the required electric power energy per unit production amount. As for the required electric power per unit production of the year 1957 we have used those which have been modified after taking into considerations of the effects such as, against the actual data in 1952 the improvement of the rate of operation of industrial facilities, modernization of the facilities, degrading of the mining condition of the mines and so forth. The production amount of the major articles and the required amount of electric energy for them for the year 1957 are given in Table 3. However, for the ordinary industries which are difficult to depend on the unit energy demand, we have forecasted the incremental rate by the actual power demand result, the forecast of the production index number and so forth.

When checking the computation result from the overall view-point, against the incremental rate 122% for the mining and industrial production index number the power demand for the year 1957 resulted in giving 128% of the year 1952 demand (assumed actual result), on account of the changes of the industrial organization and the transition of the unit energy demand etc.

b. The estimation of the non-industrial demand

(I) Electric lamps commercial use power and small power

The computation was carried out by estimating the unit energy demand per contracter or per contracted KW as well as the number of contractors or the contracted KW

The number of contractors or the number of contracted KW was based on the estimated actual result of the year 1952 plus the latest demand suppressed by the power restriction, and the annual average incremental rate obtained from the actual result of the latest few years was used for the annual incremental rate. For the unit energy demand, the value obtained by annual electric energy divided by the year end contract amount was used however it was obtained by taking into account of the increase of the electric power energy consumption amount due to the elimination of the past power restriction the improvement of the living standard, and the repletion of cultural life and so forth against the actual result of the original unit energy demand of the latest few years.

(II) The demand for the electric railway public utilities construction of power source development and etc.

Setting the incremental trend of the actual demand result of the latest few years as the criterion we have decided to add on above the demanding power energy followed with the essential expansion program of these items which could be forecasted by the end of 1957. When checking synthetically the computation result of the non-industrial use, we found out that there was an increase of 43% or annual average of 8.6%, against the estimated actual result of the year 1952, which exceeded the incremental rate of industrial use

c. Consequently, the electric power demand for the year 1957 turned out to be about 534 billion KWH. Out of this figure, we estimated 45.9 billion KWH for electric power enterprises and 7.5 billion KWH for industrial captive plants The annual peak load was estimated, taking into consideration the change of the demand composition elimination of power restriction and etc., however in the year 1957, the December peak load at the generating end of electric power enterprises resulted in the figure of 10 166 MW the annual load factor being 66%

3-2. The Course of Plan Determination

A. Target

At present, in our country we are suffering from the power shortage reaching to about 8% of the supplying capability of the normal stream flow year, consequently our government is now performing the adjust-

ment of the electric power usage. However it has now become the most urgent request of our people to solve the power shortage as soon as possible as well as to work out the reenforcement of the supplying capability complying to the future increase of demand. In this plan, the target being set for the year 1957 we are attempting to attain the balance of electric power energy at least by the year 1957. As mentioned above, the power demand for the year 1957 is 53.[illegible] billion KWH for it's annual electric power energy.

b. The composition of the plan

(I) Fund

The most serious problem for expediting the power source development is to set up the foresight of securing of the huge construction fund. Checking from the various factors such as the limitation of the self-fund which is to be procured by the companies themselves, the outlook of the government fund to be released, or the forecast of foreign fund induction and so forth; we have set up the plan of the fund limit to be 160.0 billion yen per year the power source development fund being also inclusive of that for transmission, transformation and distribution facilities.

(II) Energy resources

The energy resources in our country are chiefly made up of the comparatively abundant hydro power resources and the small amount of coal deposits. Oil and other resources are extremely little. Consequently the measures for increase in the supplying capability of hydro power turned out more to adopt the policy of hydro power "primary" and thermal power "secondary" within the allowable economical extent than in the past. In this plan, we have decided to have the annual coal consumption for electric power to be restricted to about 10033 thousand ton, which is the actual consumption in 1952 after estimating the coal production of 55000 thousand ton for the year 1957.

(III) The power source development

In case of setting up the power source development plan it is required to sufficiently study the effective combination of hydro power and thermal power in the future from the view point of electric power economics. However for the development of hydro power we must first concentrate our efforts to develop reservoir type hydro power which could be replaced for supplemental thermal power in the poor water season. Next in order to have the thermal power be operated for the

base load as much as possible, we have decided to develop the pondage type hydro power which could be adjusted during the peak hours. For thermal power plan, we have planned to set the weight on the new up-to-date thermal power to be adopted for base load operation. Since we have set the weight on hydro power development, even in the year 1957, scheduling the present existing thermal power installation to be used in the maximum extent, the restoration of its function by adding new boilers and by other remodelling measures is to be carried out, and the abolishment of low efficiency installation is to be carried out in the minimum extent.

(IV) The decrement of electric power loss

On account of the delay of completing the adjustment of the power transmission and distribution system of the electric power industry, the electric power loss has reached to 24 — 25% of the generating amount. We have considered to realize the plan of decreasing this loss dowen to 22% until the year 1957.

3-3. *The Plan for Multi-Purpose Dam*

Recently, the tendency of constructing dams on the rivers and of constructing reservoirs has become very intense due to the request brought up interiuly for agricultural, electric power and flood control purposes. However, as the rivers in our Japan, generally are of rapid current, on account of the topography we are not favoured for the sites suitable of constructing dams with high storage efficiency. Furthermore, in the gentle stream flow sites near the mountaineous area where we could expect to have a pocket of the dam, in most cases villages are developed. By these reasons, in Japan, we could say that suitable sites proposed for dam construction are very few. Therefore it is not favourable to construct dams respectively for their independent purposes, even though judging from the point of effective utilization of hydro resources or from the point of increasing the economical aspects of the various industries. As a measure of settling such various requirements simultaneously the construction of multi-purpose dam has been furthered.

The construction of reservoir type hydro power stations utilizing the multi-purpose dams are chiefly in charge of the local public agency.

3-4. *The Gist of the Plan*

The plan consists of that of the entire electric power enterprisers inclusive of the electric power companies, prefectural authorities, Power Source Development Company and the industrial captive plants. In-

cluding the hydro and thermal power source development. this plan is made up of the plans of extension and improvement works of power transmission, transformation, and distribution facilities. The figures of the plan hereunder, are for the facilities to be completed from the year 1952 to the year 1957.

a. Hydro and thermal power plan

The plan to be completed by the year 1957 consists of hydro power 3980 Megawatts, thermal power 1480 Megawatts, the total being 5460 Megawatts. Of these, hydro power 2736 Megawatts, thermal power 1149 Megawatts, total 3385 Megawatts are those already being furthered as the execution plan for the year 1952.

b. Fund plan

The total construction fund of the installation plan scheduled to be completed by the year 1957 is 852.7 billion yen, the breakdown classified in their respective kind of installation is, generation plan 460.2 billion yen, power transmission and distribution plan 301.5 billion yen, improvement works plan 91 billion yen.

3-5. *The Balance of Demand and Supply*

The supplying capability in the year 1957, for normal stream flow year is 67.1 billion KWH total inclusive of hydro and thermal power generation amount, which is possible to balance the annual electric power demand. Of this figure, the thermal power generation amount is 13.1 billion KWH. However, we are still in short of the maximum power, therefore, in order to carry out a perfect balance against the free demand, it is necessary still more to have 10% of the entire supplying capability in the normal stream flow year, as a gross margin.

4 CONCLUSION

As above mentioned, the relation of the industrial activities hereafter and the development plan of the electric power of our country is clarified. However, the economical situation in our country is exceedingly in confusion, succeptible in a great extent to the effect of the fluctuation of the international situation. Therefore, it would become necessary to modify incessantly the overall economical plan itself for the year 1957, in accordance with the outlook hereafter, as well as to reinvestigate the long term power source development plan following such modification. However the electric power situation at present is very bad, so bad that it has caused to restrict the industrial activities

of our country in a great extent. Consequently, the situation is in such an extent that power source development should be expedited by all possible means, and has turned out to be the ardent request of the general public. Consequently such trend was materialized by the legistration of the Electric Power Source Expediting Law, etc. and at present, based on such laws, we have just started in action to materialized this said plan. However, the problem still exists in the difficulty of procuring the fund thus, we have to expect on the foreign fund induction in a great extent.

TABLE I PRODUCTION LEVEL FOR MINING AND INDUSTRY

(Setting 100% for the years 1934-1936)

Kinds of Industry	Actual Result of the year 1952 (A)	Plan for the year 1957 (B)	B/A
Mining & industry	139.4	170.0	122.0
Mining	120.6	142.2	118
Manufacturing industry	140.9	172.9	123
Food industry	131.3	143.7	109
Textile industry	71.2	78.5	110
Lumber and wood product industry	158.1	173.4	110
Printing and book binding industry	107.8	103.5	96
Chemical industry	145.5	176.0	121
Rubber and hide industry	109.2	110.6	101
Ceramics	140.5	180.4	128
Metal industry	178.0	224.7	126
Machinery industry	183.9	238.0	129

The above index was computed considering the weight based on the value appurtenant respectively to the 85 items adopted.

TABLE 2. THE DEMAND OF THE ELECTRIC POWER FOR THE YEAR 1952 AND FOR THE YEAR 1957

(Unit: 10^6 KWH)

	Estimated Actual Result (for the year 1952)	Plan for the year 1957	
(1) Industrial use	20,387 7	36,347 7	
(a) Mining			
Coal	2,784 7	3,521 0	
Others	1,113 7	1,467 6	
(b) Metal industry			(Besides the items written in Table 3 (This includes the secondary products, etc)
Steel	3,071 9	4,000 0	
Aluminium	1,017 7	1,400 0	
Others	755 0	605 4	
(c) Machinery & appliances industry	1,496 4	2,118 5	
(d) Chemical industry			
Carbide & calcium cyanamide	2,597 3	3,695 0	
Ammonium sulphate	3,613 0	3,730 0	Electrolysis and gas method
Paper, pulp	1,631 1	2,311 6	
Rayon and stable fibre	1,025 5	1,276 1	
Others	2,294 9	2,690 5	
(e) Ceramics			
Cement	916 9	1,212 0	
Others	570 1	707 5	
(f) Textile mfg industry	1,531 8	1,749 6	
(g) Others	1,290 3	1,652 2	
(h) Sub-Total	29,674 6	42,706 4	
(i) Small power	2,511 1	3,639 3	Max power less than 50 KW
(2) Non-Industrial use	11,929 5	17,047 1	
(j) Commercial use power	7,821 1	11,064 7	
(k) Household & other non-industrial use	4,106 4	5,983 2	Electric railway, public utilities & others
(3) Demand Total (1) (2)	40,317 2	59,755 0	

Remarks The figures above are the total for the electric power enterprises and for the industrial captive plants, computed at the consumers

TABLE 3 PRODUCTION PLAN CLASSIFIED IN THE MAJOR ITEMS

Required Electric Energy as well as the Unit

Energy Demand Adopted

(For the year 1953)

Items / Article	Production amount (10^3 t)	Required electric energy 10^6 KW	Unit energy demand (KWH t)
Coal	55,000	3,523.0	65
Shaft furnace pig iron	5 350	294.0	55
Electric pig-iron	210	630.0	3,000
Electric furnace steel ingot	1 000	850.0	850
Open hearth steel ingot	6 410	147.0	23
Bessemer converter steel ingot	250	22.5	9
Ferro-alloy	100	620	6 200
Ordinary steel	5 000	825	165
Special steel	340	119	350
(Electrolytic-process)	600	2 220	3,700
(Ammonium (electrolytic-process)	1 820	1 510	830
Sulphate (gas-process)	65	1,400	21,500
Carbide	940	3 290	3,500
Calcium cyanamide	700	315	450
Cement	9 200	1 242.0	135

Remarks (1) For the estimation of power demand for the year 1957 given in Table 2 the figures for the 5 items coal steel carbide and nitrogen sulphate were based on this tabulation.

(2) The unit energy demand is inclusive of not only for the production directly necessary but also for that is necessary indirectly such as maintenance, safety and so forth

Summary

In Japan we have set up the 5 year electric power development plan ending in the year 1957 In setting up this plan first, we have forecasted the trend of the living standard and the economical activities of our people Under such forecast we have computed the necessary power demand That is — for the estimation of power demand for non-industrial purposes such as household use power commercial use power public utilities use power and etc we have computed the growth of no. of contracts or the contracted Kw and the growth of electric power energy to be consumed on the basis of per unit number of demand, derived from the population and the trend of the living standard.

Furthermore for the demand estimation for industrial use power, we have computed from the basis of the estimated amount of production for the various industries as well as the electric power energy to be consumed per unit amount of production in our country On the other hand, for the development of hydro power generation, we have set the weight on the reservoir type generation utilizing the multi-purpose dam which particularly has the relation with the preservation of mountains flood control and irrigation water In this paper we have explained in details by giving examples on the method for determining the electric power plan

Résumé

Au Japon on a établi le plan de cinq ans de l'exploitation de l'énergie électrique lequel se terminera en 1957 Pour établir ce plan, on a estimé la variation du niveau de la vie nationale et de l'activite economique, et sous cette estimation on a tenu compte du besoin de l'energie électrique nécessaire Pour estimer le besoin de l'énergie électrique non industrielle telle que l'energie électrique de la famille, l'énergie electrique commerciale celle d'usage public etc., on a tenu compte de l'augmentation du chiffre des cas de contract ou des kilowatts contractes et de celle de la consommation de l'energie électrique par unite de ce chiffre, ces augmentations étant estimees par la variation supposee de la popu-

lation et du niveau de la vie nationale; et pour estimer le besoin de l'energie electrique industrielle, on a tenu compte de l'estimation de la quantite de production dans les différentes industries et de la consommation de l'energie electrique par unité de production. Pour etablir le plan de production de l'énergie electrique, correspondant a l'estimation du besoin, on a tenu compte de la quantité de production de l'energie thermo-électrique cette quantite etant estimee par les ressources du combustible utilisables chez nous, et de la quantité de production de l'energie hydro-electrique, cette energie etant produite en particulier par les reservoirs utilisant les barrages de plusieurs buts, qui ont la relation avec la preservation des montagnes, la protection contre l'inondation et l'irrigation. Dans cette these on exposera la méthode concrete de l'établissement de ce plan electrique, en y ajoutant les exemples.

Resumo

Estabeleceu-se no Japão, o plano de cinco anos para a exploração da energia eletrica o qual terminará em 1957. Para estabelecer êste plano, estimou-se a variação do nivel de vida nacional e da atividade econômica. Sob esta estimativa, levou-se em conta a necessidade da respectiva energia eletrica. Quer dizer para a estimativa do necessario a energia eletrica não industrial tais como a energia elétrica domestica comercial publica etc levou-se em conta o aumento do numero dos casos de contratos ou de kilowatts contratados e o consumo de energia eletrica por unidade dêsse numero tais aumentos sendo estimados pela variação da população estabelecida e pelo nivel de vida nacional. E para estimar-se a necessidade de energia elétrica industrial, levou-se em conta a estimativa da quantidade de produção nas diferentes industrias e o consumo de energia eletrica por unidade de produção. Para estabelecer o plano de produção de energia elétrica correspondente à estimativa das necessidades levou-se em conta a quantidade de produção de energia termo-elétrica sendo esta quantidade estimada pelos recursos de combustivel utilizados entre nós e a quantidade de produção de energia hidro-eletrica tal energia sendo produzida em particular pelos reservatórios que utilizam as barragens de vários fins, que tenham relação com a preservação das montanhas, a proteção contra inundação e a irrigação. Nesta monografia, expõe-se o método concreto do estabelecimento dêsse plano eletrico acompanhado dos respectivos exemplos.

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YAMAZAKI (K.)
Japão

THE JOINT UTILIZATION OF HYDRO AND THERMAL ELECTRIC POWER IN JAPAN

By TOSHIO YOSHIOKA
[illegible]

and KYUICHI YAMAZAKI
[illegible]

JAPANESE NATIONAL COMMITTEE

1 — INTRODUCTION

The joint system of hydro primary and thermal secondary was developed as the fundamental of power source development in Japan. In the background of this system for being developed in Japan, the special feature of the energy resources of Japan has a great factor. That is, the energy resources of Japan is chiefly made up of the comparatively large hydro resources and the small amount of coal deposits. Oil and other resources are extremely small. By effectively utilizing this comparatively abundant hydro resource and thus economizing the consumption of this meagre fuel resources, lowering the generation original cost is the basic idea for the joint utilization of hydro and thermal power in Japan.

This paper exclusively introduces the theoretical ground of the joint utilization of thermal and hydro power, the so called "hydro primary thermal secondary" regarding that of the pre war years (from 1930 to 1940). The construction plan of hydro and thermal projects in Japan prior to the termination of the last war has been most instructed in accordance to the system explained in the conclusion of this paper.

2 — THE PRECEDING CONDITIONS FOR THE THEORETICAL DEVELOPMENT

The essential point of the economical study of the joint utilization of hydro and thermal power should be to determine the extent of the joint utilization of hydro and thermal power for the purpose of minimizing the overall electric power original cost, by the analyzation of the installation capacity of the hydro and thermal power plants, the construction

cost, special character of the hydro power plant, the load to be taken by these two and the generation original cost. Hereunder, we would like to explain the necessary preceding conditions briefly, before furthering the theory for this objective.

2.1 *Regarding the Classification of the Hydro and Thermal Power Generation System*

As for the combination on utilizing hydro and thermal power jointly, we would like to set eight classes of the typical generation system as mentioned hereunder, and thereon, to be as the creterion for the computation of figures.

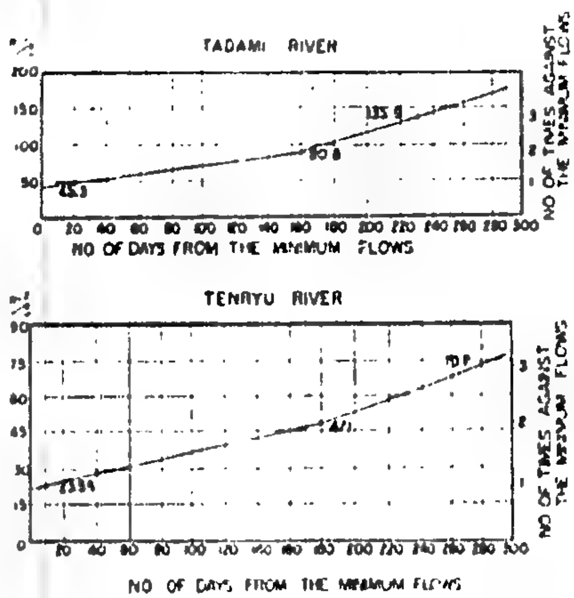


Fig. 1 —Duration curve of stream flow

(A): For the case, operating the non-pondage type power plants without simultaneously running the thermal power plants during the rich water season, and to operate the thermal power generation for peak loading, and hydro generation for base loading during the poor water season (Refer Fig. 6)

(B): For the case that although the power plant being of pondage type, this plant is to be operated without water control during the rich water season on account of there being no enerating facilities for controlling the water amount, however the thermal power generation is not to be performed jointly. But, during the poor water

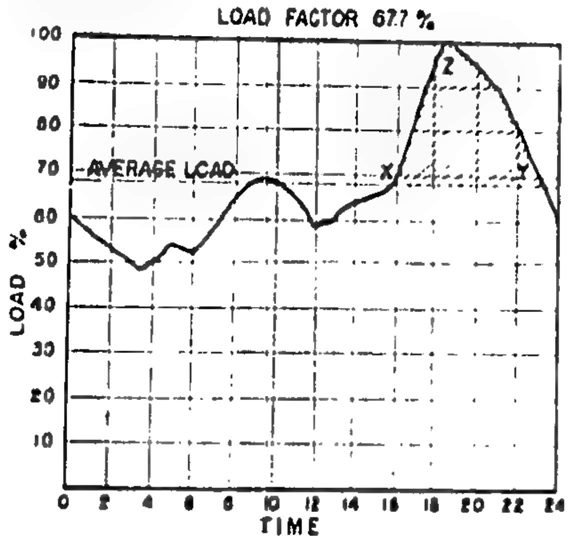


Fig 2 — Typical load curve

season, the peak loading is to be performed by controlling the discharge and to have the thermal generation furnish the basic load (Refer Fig 7)

(C) For the case of pondage type hydro power plant operated fully during the rich and poor water season, and not utilizing the thermal power generation jointly, during the rich water season. However, during the poor water season, the peak load is to be furnished by hydro generation and the base load by the thermal power generation (Refer Fig 7)

(D) For the case of operating the non-pondage type hydro power plant for base load during both the poor and rich water seasons and to jointly utilize the thermal generation for supplementing the poor water power as well as for peak loading during the poor and rich water season respectively (Refer Fig 9)

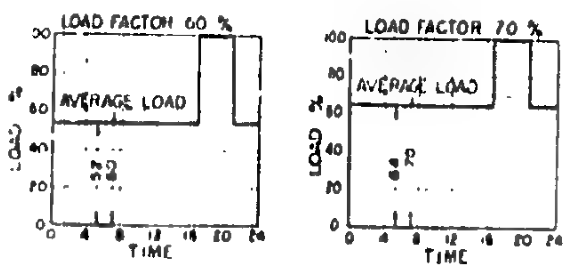


Fig 3 — Rectangular load curve

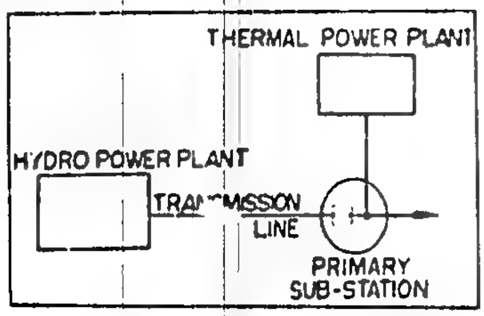


Fig. 1 — Electric power generation and transmission system diagram

(D) For the case that being a pondage type hydro power plant, hydro generation is to be utilized for base loading and thermal for peak loading during the rich water season, on account of there being no generating facilities controllable for the water amount. However, during the poor water season, the hydro generation is to be utilized for peak loading by utilizing the pondage with the thermal power generation to be operated for base load. (Refer Fig. 10)

(E) For the case of pondage type hydro power plant with the water amount controlled and utilized in a certain extent even during the rich water season, and at the same time to make up the deficit of the peak load by the thermal generation. However, during the poor water season, the hydro generation is to be utilized for peak loading by utilizing the pondage, and at the same time to operate the thermal plants for base loading. (Refer Fig. 11)

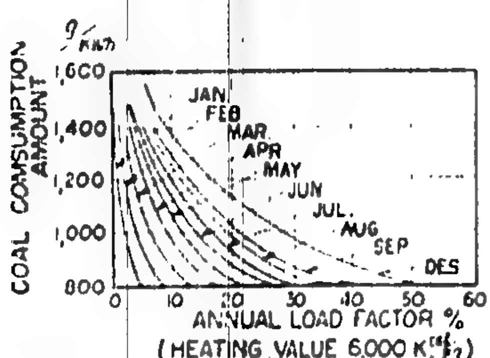


Fig. 5

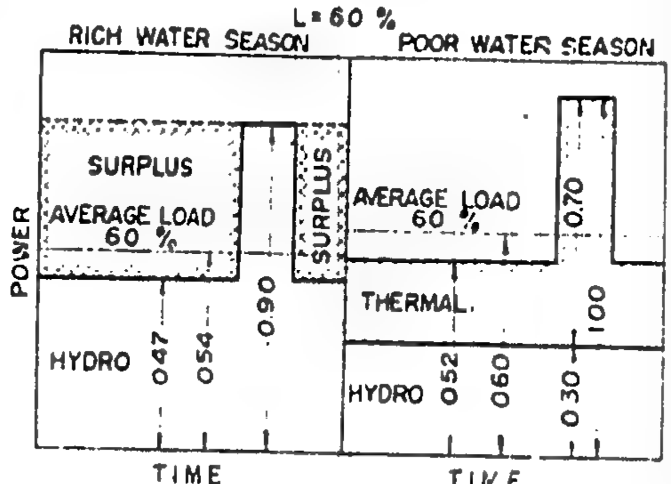


Fig. 6 — The joint utilization of hydro and thermal power under the system (A).

Remarks : 1 — Annual peak load in poor water season (converted to hydro) is to be set as 1.00

2 — Setting j 3

3 — L 70% is to be eliminated

(— · — · — line indicates the average load)

4 — The same is to be aplied hereafter for the diagrams Fig. 7 to Fig. 13.

(G): For the case of rich water season thermal power of case (F) decreased to one half (Refer Fig. 12).

(H): For the case of rich water season thermal power of case (F) entirely abolished (Refer Fig. 13).

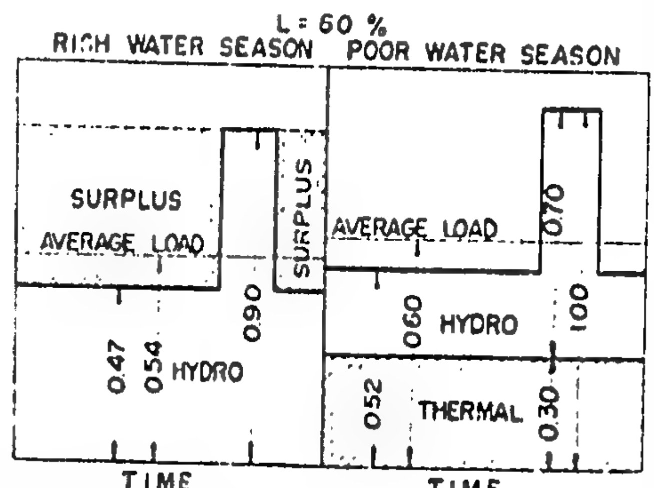


Fig. 7 — The joint utilization of hydro and thermal power under the system (B).

2.2 *Regarding the Stream Flow of Hydro Sites*

For the convenience of simplifying the problem under this study, we have selected certain stream flow gaging sites on the Tadami River (pouring into the Japan Sea) and Tenryu River (pouring into the Pacific Ocean) for the purpose of comparing these two cases which have a considerable difference in the annual stream flow variation. Generally, these stream flow curves could be represented by the quadratic curve $Q = a + bn + cn^2$. However, in this case, as we have confirmed that the accuracy would not be particularly reduced even though by replacing these curves simply by two or three refracted straight lines, we have decided to use the refracted straight lines as given in Fig. 1.

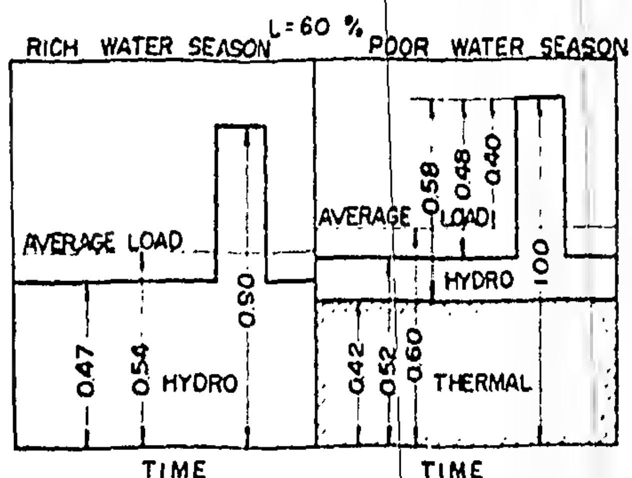


Fig. 8 — The joint utilization of hydro and thermal power under the system (C).

2.3 *Regarding the Estimated Load Curve*

As a typical load characteristic of the central part of Honshu (Main Island of Japan), we would like to use the average load characteristic of Tokyo, Osaka and Nagoya.

a. Annual load curve

The variation rate of the load in a year is that, representing the mean peak load for the respective month, by setting the mean value of peak load for the ten days from December 15 to December 21 (excluding Sundays) as 100%, we have discovered that the peak load is approximately near 90%. Consequently, hereunder assuming the peak load

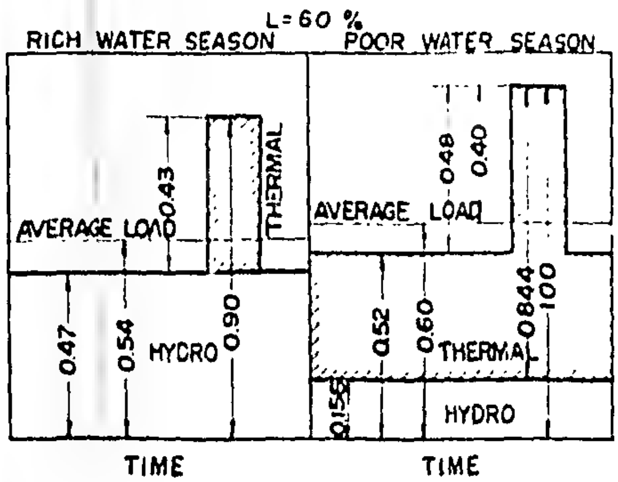


Fig. 9 — The joint utilization of hydro and thermal power under the system (D).

to be constant throughout the year and setting this constant equivalent to 90% of the peak load during the end of December, we have adopted this figure for the computation hereafter.

b. Daily load curve

We have set the typical daily curve as given in Fig. 2 which could be approved as approximately average of the annual load curve. However, in the various generation systems which are the object of this chap-

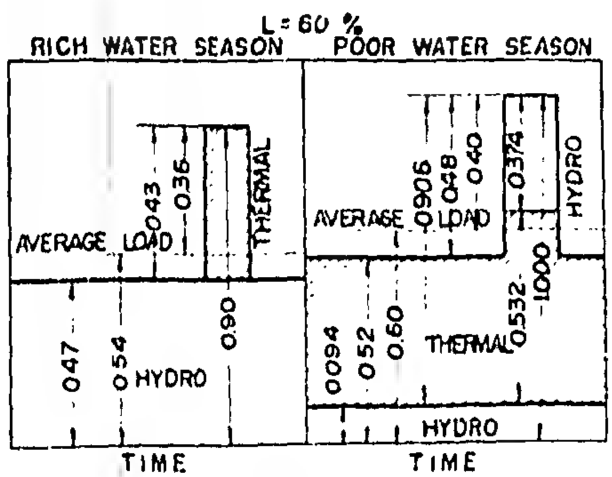


Fig. 10 — The joint utilization of hydro and thermal power under the system (E).

ter, in case of studying the relation between the water amount to be used and the original cost of the electric power, there is no great difference in the result, even though using the rectangular load curve as given in Fig. 3, instead of Fig. 2. Moreover, as we have confirmed that it is quite advantageous for the computation, hereafter, setting this as constant throughout the year, we have set this as the criterion for all computations. Furthermore, the reason we have 70% and 60% for the load factor in Fig. 3 is that, the former is to indicate the present situation

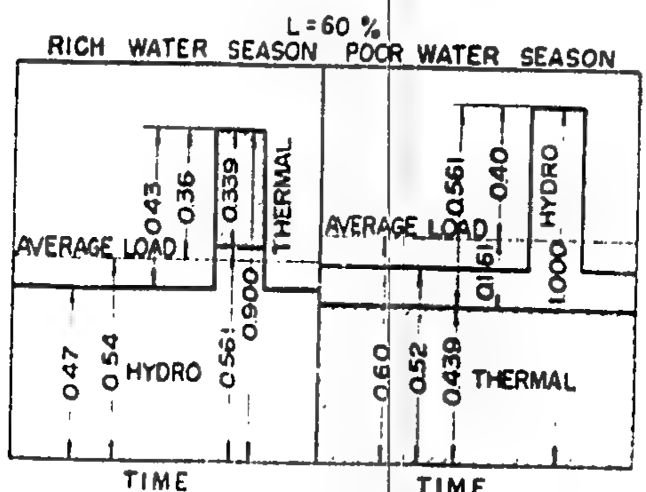


Fig. 11 -- The joint utilization of hydro and thermal power under the system (F).

(at that time) and the latter for the future, whereas the continuation time of the peak load is set as 4 hours each day (computed by dividing the area of xyz portion in Fig 2 by it's height).

2.4 *Regarding the Water Amount to be Used*

From the viewpoint of the effective usage of water, although the discharge utilized in the power plants has the tendency of increasing every year, arbitrarily, we have worked out the computation setting j = 3 as the criterion, ($j = \dfrac{\text{maximum discharge}}{\text{MINIMUM FLOW}}$, whereas for the case of the controllable discharge during the rich water season, the average discharge prior to the control is to be set as the maximum discharge), with the comparison being performed for the case of varying j between 1 to 3

2.5 *Regarding the Power Generation and Transmission System*

As shown in Fig. 4, the hydro power is sent to the primary sub station which is located nearest to the demand site, and is to be combined together with the thermal power at the secondary side bus of this said substation. Therefore as far as the electric power original cost is concerned, this cost was computed against the supplying electric power at the secondary side bus of the primary sub-station. In addition, for the convenience of simplification, the total power transmission loss rate up to that end, has been assumed as 10%, regardless of what the load may be.

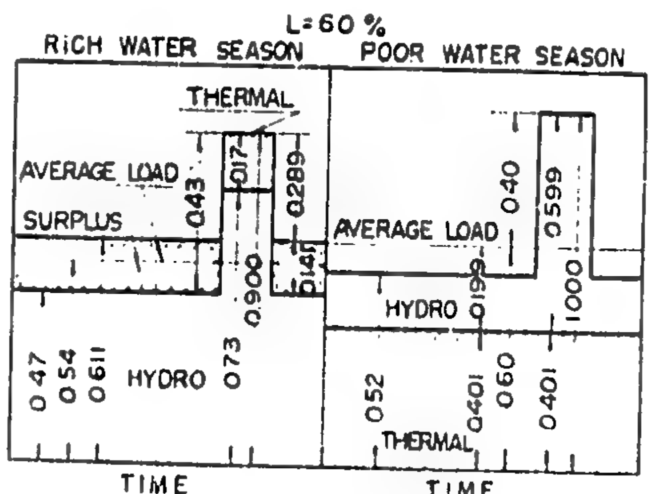


Fig. 12 — The joint utilization of hydro and thermal power under the system (G)

2.6 *Regarding the Construction Cost, the Fixed Expense and the Variable Expense of the Electrical Installation*

The following are the major computation grounds of the construction cost, fixed expense and the variable expense of the respective electrical installation.

a. Construction unit cost of hydro power plant

Setting the criterion so as to design the discharge to be twice the minimum flow (j = 2), the variation of the construction unit cost in case of the discharge (Q m³/s) being varied, was assumed to be in proportion to $Q^{-1.3}$, $Q^{-1.4}$ and $Q^{-1.5}$, in accordance with the design

Remarks:

(1) If pondage is not to be installed (system (A) and (D)), it is assumed that, it is in proportion to $Q^{-1.3}$ or $Q^{-1.4}$.

(2) Although the pondage is to be installed, in case the controll during the rich water season is not to be carried out (system (B) and (C)), then it is assumed that it is in proportion to $Q^{-1.4}$ or $Q^{-1.5}$.

(3) In case of installing a pondage controllable even during the rich water season (corresponding to system (C), (F), (G) and (H)), the pondage construction cost being excluded, and setting j = 2, then it is assumed as similar to the case of (1), and then 80 yen per KW of controllable capability concerning the pondage is to be added. However, the pondage is to be installed near the end of the waterway, adjacent to the power plant.

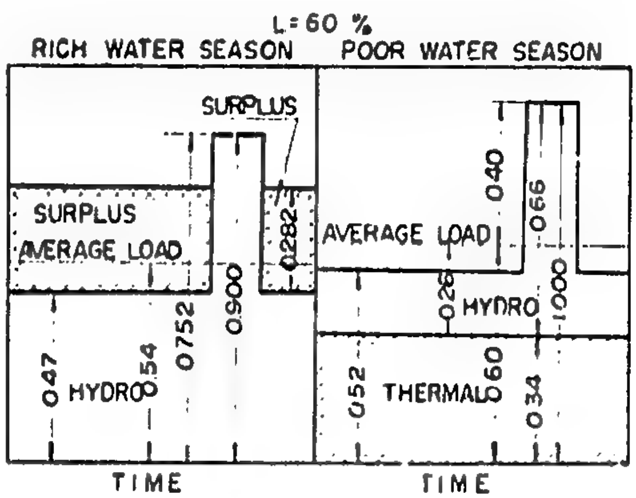


Fig. 13 — The joint utilization of hydro and thermal power under the system (H).

(1) At this time Yen value is about half of one U. S. Dollar.

b. The construction unit cost of thermal power plant

The construction unit cost of the supplemental thermal power plant shall be 80% of that of the firm plant.

c. The coal consumption rate

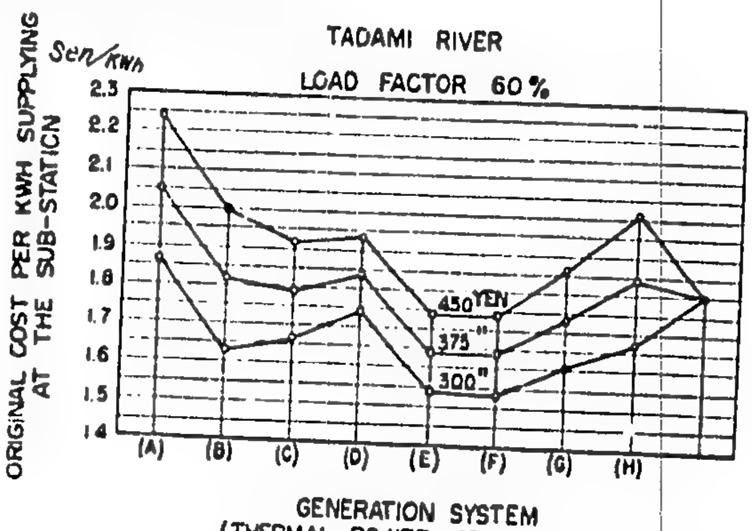


Fig. 14 (1) — Original cost of electric power (the effect of the construction cost of hydro power plant).

Assuming that the coal consumption rate per kWh of the generation electric energy of the thermal electric power plant, varies depending on the annual load factor and the number of operating months of the power plant, we have decided to use Fig. 5 diagram.

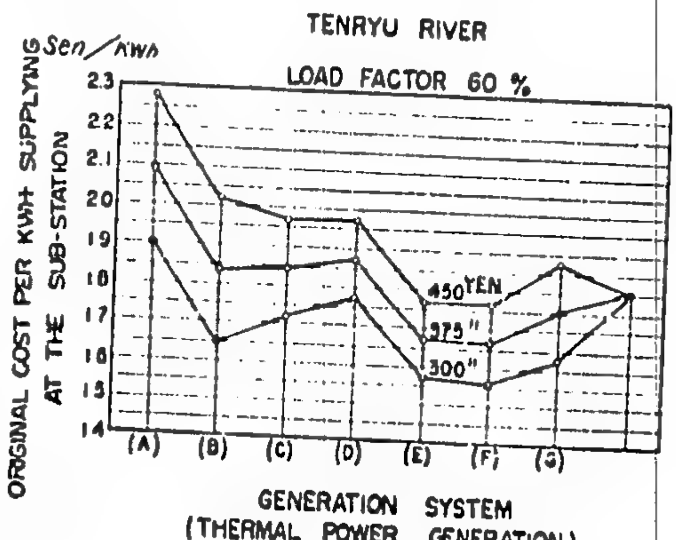
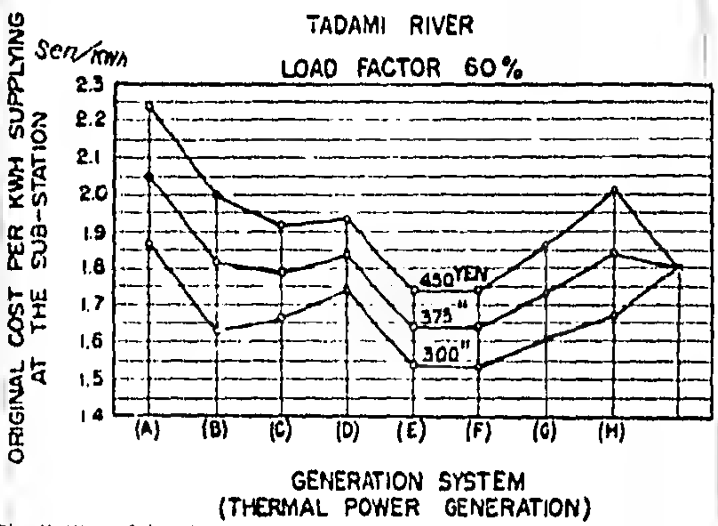


Fig. 14 (2) — Original cost of electric power (the effect of the construction cost of hydro power plant).



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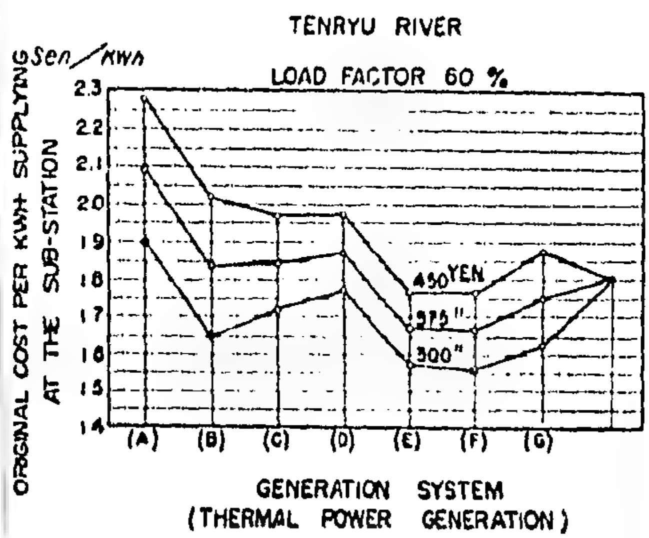

Fig. 14 (2) — Original cost of electric power (the effect of the construction cost of hydro power plant).

d. The profit rate

The standard shall be 10% against the construction cost.

3. THE THEORETICAL CONSIDERATION

3.1 *The Qualitative Consideration*

Although, we have set up the combinations and the classification of hydro and thermal power, arbitrarily conceivable, as mentioned in the previous paragraph (refer 2.1), we would like to perform the qualitative consideration regarding these 8 cases.

As system (A) and (D) do not have controlling capability even during the poor water season, the output of the supplemental thermal power becomes large as well as its load factor is low compared with the system

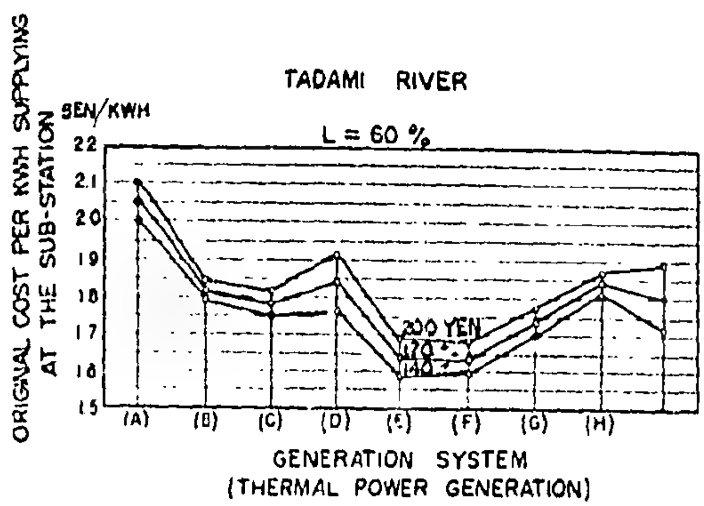

Fig. 15 — Original cost of electric power (effect of the thermal power plant construction cost)

Remarks 1 — The number written on the curve is the construction cost of thermal power plant (Yen kW)
2 — Sen values one hundredth of Yen.

having controlling capability. Furthermore, system (A), (B), (C) and (H) supply the load only by the hydro during the rich water season, and the thermal power is used only for the poor water season replenishment. System (D), (E), (F) and (G) jointly utilize the thermal power in the peak loading period even during the rich water season. Consequently from the viewpoint of the economical utilization of water, generally, the latter is superior to the former. However, whether which system would become

[illegible] electric power original cost, it shall become clear, by computing and comparing the electric power original cost, for the 8 various combinations.

3.2 *Quantitative Consideration*

The maximum capacity and the annual generating electric energy of the respective joint utilization system for the hydro and thermal power plants, could be computed by proper equation, after assuming the load curve and the stream flow curve previously mentioned. In this paper, the equation and its induction method are eliminated. The computation result concerning Tadami River and Tenryu River is given in Table 1.

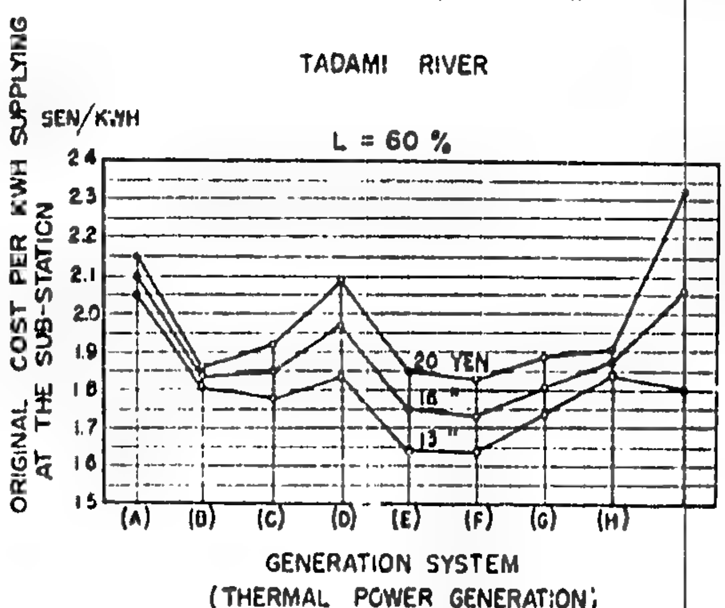

Fig. 16 — Original cost of electric power (effect of the coal price).
Remark : The number written on the curve is the coal price (Yen ton)

Although these figures are the basic data for the computation of the generation original cost, for the convenience of comparison, the annual maximum peak load (converted to hydro power generation) is represented as 1 KW.

4. REGARDING THE GENERATION SYSTEM AND THE ELECTRIC POWER ORIGINAL COST

If computing the electric power original cost against the various generation systems (in case of ρ = 3), with the basis set on the figures of Table 1 and the construction cost and the various expenditures given

TABLE I

(1) Tadami River (L ~ 60%)

Generation system	Hydro plant output (kW)	Thermal plant output (kW)	No. of operating days per year by thermal plant	Thermal power generating energy per year (kWh)	Ratio of thermal power generating energy per year to Total electric energy to be supplied per year (%)	Annual load factor of thermal plant (%)	Coal consumption (kg)	
							per kWh generation by thermal plant	for total
A	0.900	0.700×0.9	230(77)	487×0.9	10.30	7.94	1.29	565
B	0.900	0.300×0.9	128(43)	369×0.9	7.80	14.05	0.88	291
C	0.900	0.420×0.9	230(77)	1,188×0.9	25.12	32.30	0.81	865
D	0.468	0.844×0.9	365(120)	1,661×0.9	35.10	22.46	1.08	1,615
		*0.432×0.9	** 230(77)					
E	0.468	0.532×0.9	365(120)	1,661×0.9	35.10	35.65	0.91	1,350
		*0.432×0.9	** 230(77)					
F	0.561	0.439×0.9	365(120)	1,562×0.9	33.00	40.60	0.86	1,212
		*0.339×0.9	** 230(77)					
G	0.691	0.401×0.9	365(120)	1,152×0.9	24.37	32.80	0.94	970
		*0.208×0.9	** 198(66)					
H	0.900	0.341×0.9	166(55)	560×0.9	11.83	18.73	0.66	435

TABLE I

(2) Tenryu River (L = 60%)

Generation system	Hydro plant output (kw)	Thermal plant output (kw)	No. of operating days per year by thermal plant	Thermal power generating energy per year (kwh)	Ratio of thermal power generating energy per year to Total electric energy to be supplied per year (%)	Annual load-factor of thermal plant (%)	Coal consumption (kg) per kwh generation by thermal plant	Coal consumption (kg) for total
A	0.900	0.700×10^9	280 (93)	573×10^9	12.12	9.35	1.30	867
B	0.900	0.300×10^9	147 (47)	435×10^9	9.18	16.55	0.85	334
C	0.900	0.420×10^9	280 (93)	$1,300 \times 10^9$	29.18	37.50	0.82	1,020
D	0.468	0.844×10^9 $*0.432 \times 10^9$	365 (120) ** 280 (93)	$1,826 \times 10^9$	38.60	24.70	1.04	1,740
E	0.468	0.532×10^9 $*0.432 \times 10^9$	365 (120) ** 280 (93)	$1,826 \times 10^9$	38.60	39.18	0.87	1,440
F	0.561	0.439×10^9 $*0.339 \times 10^9$	365 (120) ** 280 (93)	$1,731 \times 10^9$	36.58	45.00	0.83	1,297
G	0.561	0.401×10^9 $*0.208 \times 10^9$	365 (120) ** 232 (77)	$1,271 \times 10^9$	26.87	36.20	0.[illegible]	1,030

Remarks : Same as that of "(1) Tadami River, L = 60%".

(1) Total electric energy to be supplied per year means the energy to be supplied at the sub-station.

(2) * Firm power from the thermal power plant which is the portion of the output, and could be used every day throughout the year.

(3) ** In case of performing thermal power generation throughout the year, the number of days in which thermal power generation is to be carried out for replenishment during the poor water season.

in 2.1.6, the result is as shown in Fig. 14, (1) and (2). This diagram, adopting the standard figures under the above mentioned assumption, is the result of the computation worked out in connection with the 3 classifications, the first, second, and third simply on the hydro power plant construction unit cost. As obvious from this said diagram, we could see that the system which have the lowest electric power original cost per kWh of supplying electric power energy is (F) and (F) whether in the case of Tadami River or Tenryu River, or whatever hydro power generation station construction unit cost. In other words, this is the case of adopting the generation method so as to raise the utilization factor of stream flow of hydro power plant by utilizing the thermal power jointly in the peaking period, during the rich water season, together with that of raising the load factor of thermal power plant by effectively utilizing the pondage during the poor water season. Following this, the generation system, which utilizes the pondage, and controlls its water, as in the case of (G), (B) and (C), becomes advantageous when the construction unit cost of hydro power plant becomes particularly low.

1.3 *The Effect on the Electric Power Original Cost Caused by the Variation of the Various Expenditures*

As previously mentioned, Fig. 14 is the case of varying only the construction unit cost of the hydro power plant, adopting the standard expenditures for the other factors. However, hereunder the construction cost being set as the standard unit cost; Fig. 15, Fig. 16 and Fig. 17

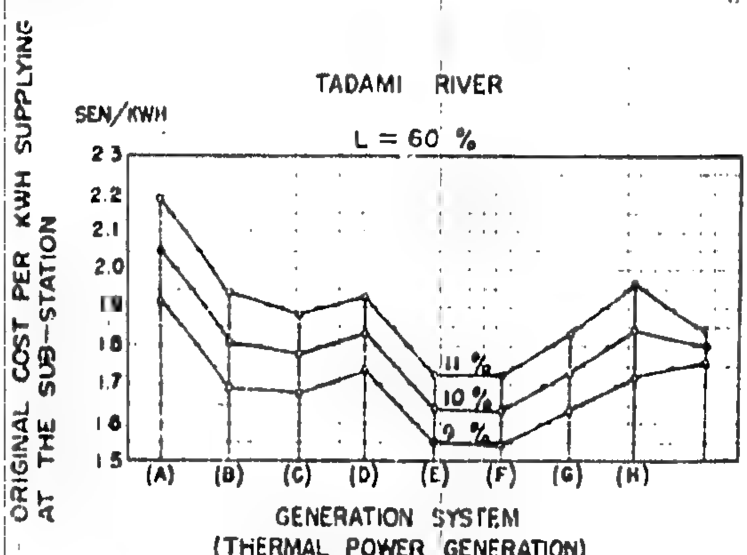

Fig. 17 — Original cost of electric power (effect of the profit rate).
Remark : The number written on the curve indicates the profit rate (%.)

show the effect given to the electric power original cost, when varying the construction unit cost of the thermal power plant, the coal price and the interest. In any case, the cases of the generation system (E) and (F) are the most advantageous, however, when the construction unit cost of the thermal electric power plant is low, the case of (D) is also advantageous in parallel with (B), (C) and (G). Next, in case of the fuel cost becoming high, the system of (E) and (F) will tend to decrease its superiority, reaching to the stage of not having a large difference with (B), (C) and (G). Furthermore, the effect on the interest has the same trend as the variation of the construction unit cost of the hydro electric power plant.

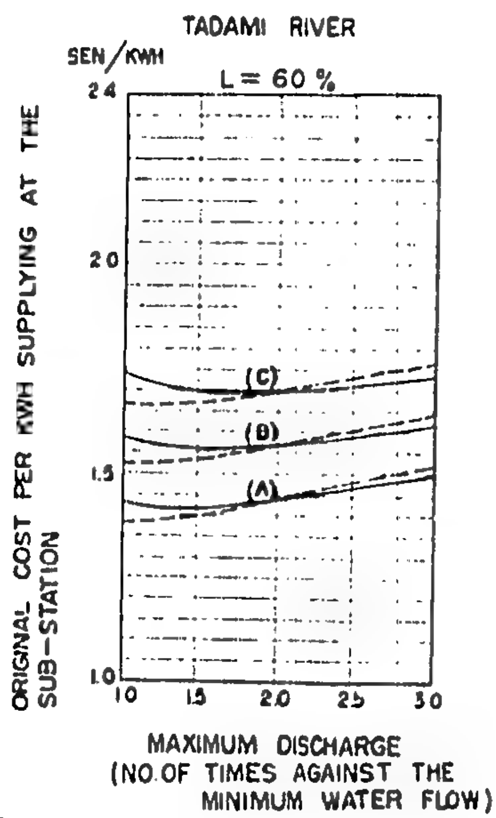

Fig. 16 — Electric power original cost in system (E).

Remarks : 1 — Thermal power plant construction cost 170 Yen kW.
2 — Coal price 13 Yen ton.
3 — ——— line is the case when hydro power plant construction cost is proportion to $Q.^{1.4}$.
4 — ——— line is for the case being proportional to $Q.^{1.8}$.
5 — (a), (b) and (c) indicate the hydro power plant unit construction costs at j ·· 2,350 Yen, 450 Yen and 550 Yen respectively.

5. REGARDING THE DISCHARGE TO BE USED, AND THE ELECTRIC POWER ORIGINAL COST

In the previous paragraph 4, we have known that we could obtain the minimum electric power original cost in the case of (E) and (F) under any condition of the various expenses, when the maximum discharge of the hydro electric power plant is equal to three times that of

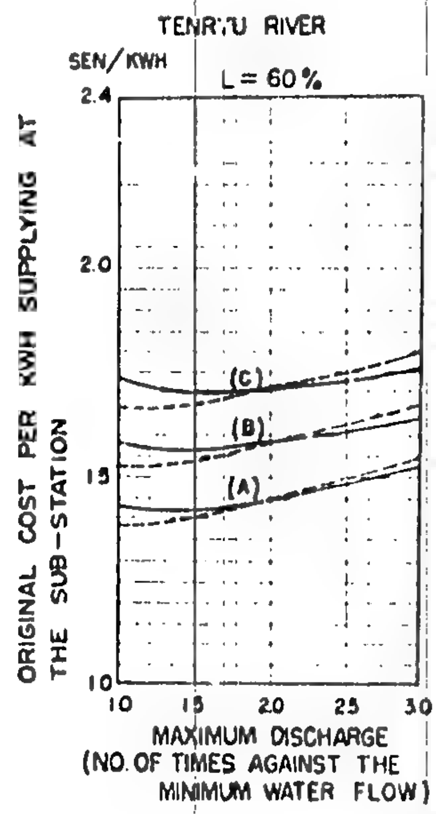

Fig. 19 — Electric power original cost in system (E).
Remark : Same as that of Fig. 18.

the minimum water flow, that is j = 3. In this paragraph, the consideration is to be furthered additionally, by investigating the effect on the electric power generation cost in case of varying j in the system (E).

5.1 *In case of Varying the Construction Unit Cost*

In case of varying j from 1.0 to 3.0, assuming that the construction unit cost of hydro power plant is to be proportional to $Q^{-1/3}$ or $Q^{-1/2}$, as given in 2.6. a, Fig. 18 and Fig. 19 shall give the picture of the

variation of the electric power original cost, setting the construction unit cost as a = 350 yen/kW, b = 150 yen/kW and c = 550 yen/kW for the case of J = 2. That is — in case of being proportional to $Q^{-1/4}$, the electric power original cost will become the minimum for J = 1.5 ~ 2.0, and of being proportional to $Q^{-1/8}$, it will become the minimum for J = 1.0 ~ 1.5. However, in any place, the variation of electric power original cost due to the variation of j is not so great.

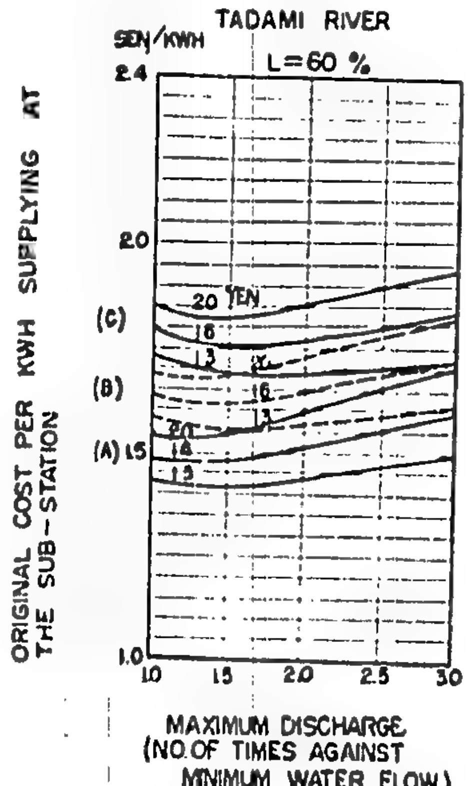

Fig. 20 — The effect inflicted on the electric power original cost by variation of coal price (system E).

Remarks : 1 — Thermal power plant construction unit cost 170 Yen/kW.
2 — The numbers written on the curves are coal price, Yen per ton.
3 — The hydro power construction unit cost is to be proportional to $Q^{1/4}$.

5.2 *In case of Varying the Coal Price and the Construction Unit Cost of the Thermal Power Plant*

This is exactly as given in Fig. 20 and Fig. 21, however in any case, the increasing trend of the coal price and the construction cost has the tendency to shift the value of j which causes the original cost of the

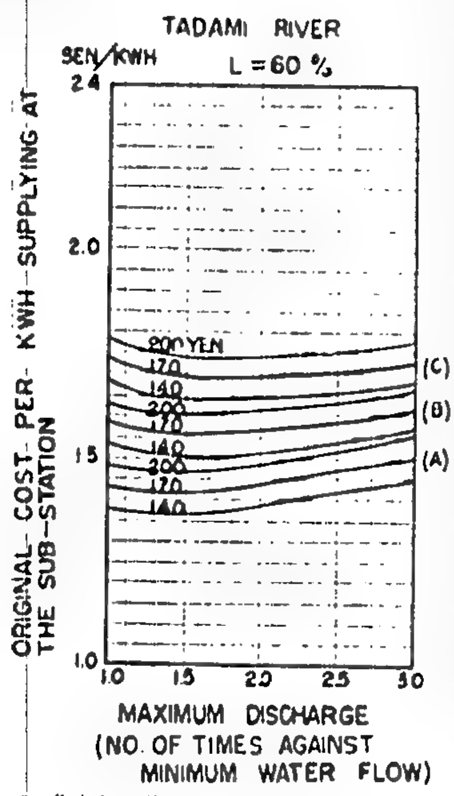

Fig 21 — The effect inflicted on the electric power original cost by the variation of thermal power plant construction cost (system E).

Remarks 1 — The numbers written on the curves are the thermal power plant construction unit costs.

2 — Coal price 13 Yen ton.

3 — The hydro power plant construction unit cost is to be proportional to $Q^{1.4}$.

electric power to be minimum towards the smaller value, that is — has the tendency of approaching to the value of 1.0, however its effect is extremely small. Even though performing the above mentioned computation on the various systems besides the generation system (E), we could justify that the effect on the electric power original cost due to the variation of j, is not so great for any of the systems excluding the system (D). Consequently, even though adopting the design to have the discharge set about 2 to 3 times that of the minimum water flow, the increase of the original cost of the electrical power due to the above treatment, could be said to be in the economical extent sufficiently permissible.

6 CONCLUSION

6.1 The conclusion that could be derived from the computation result of paragraphs 1 and 5 mentioned above is that,

a Compared with other various systems the composite original cost of the electric power becomes the minimum, by installing pondage for the hydro electric power stations, utilizing the hydro power particularly during the poor water season for peak load, and thereby reducing the installation capacity for supplemental thermal power plant, as well as increasing the load factor and to obtain the advantageous operation of the thermal power plant, together with the steps to supply the peak load by the thermal power during the rich water season so as to prevent the unavailable spill

b The discharge to be used for the hydro power plant against the minimum water flow, is that even though increasing this said amount, the effect to be inflicted on the composite original cost of the electric power is exceedingly slight Although, we are told that the hydro generation is very abundant in Japan, the generating capability of a single site available from the minimum water flow design is small, and so it is very difficult to cover the power demand simply depending on the hydro power plants of this type. Therefore, for the purpose of utilizing the hydro power resources of Japan as effectively as possible, it is desirable that the maximum discharge of the hydro power plant is set about two to three times that of the minimum water flow

6.2 From the above viewpoints, as a basic policy of power sources development in the area which is comparatively abundant in the hydro power resources of our country, we consider that the three to four months stream flow (approximately three to four times the minimum water flow) should be adopted as the standard discharge for the hydro power plants design, together with the idea of installing pondages or reservoirs, as well as to utilize the thermal power generation for replenishing the drought during the poor water season, and for peak loading during the rich water season

SUMMARY

The hydro electric power plants in Japan has adopted the policy of designing the maximum discharge to be 3 to 4 times of the minimum flow ever since the prewar years On the other hand, the thermal power plants were constructed under the policy of chiefly supplementing the poor water The reason why such course was taken as to set the hydro power as the primary power and thermal power as the secondary, is

due to the fact that the hydro resource is comparatively abundant, while the fuel resources such as coal and oil are meagre, as far as the situation of relying on the energy resources in Japan is concerned. It is also due to the fact that, in compliance with the power source development, such course is advantageous economically for the electric power generation. In the past, in order to find out the most economical manner of the joint utilization of hydro and thermal power generation, we have performed numerous studies in Japan. In this paper, we have made comparison studies on the various manners of the joint utilization of hydro and thermal power generation, and in regard to such studies, we have derived the conclusion. That is — in case of jointly utilizing the hydro and thermal power plants, we have reached to the conclusion that the most economical generation manner is to utilize the hydro generation for peaking purpose during the poor water season with pondages installed for the hydro plants, as well as to utilize the thermal generation for base loading thus making it possible to decrease the installation capacity of supplemental thermal power plants, increase it's load factor and it's generating efficiency. Furthermore, during the rich water season, the thermal generation is to be jointly utilized for peaking purpose in order to decrease the spilling flow of the hydro plants. Furthermore in this paper, we have pointed out that, it becomes most economical to set the maximum discharge of the hydro plants in the extent of 1.5 to 2 times that of the minimum flow. However, we have also pointed out that even though, increasing this figure to 3 to 4 times, the generation original cost hardly increases, as well as that by following such we could work out the effective utilization of hydro power resources

Résumé

Pour les centrales hydrauliques du Japon, on adoptait dès avant la guerre le principe de fixer sa décharge maximum 3 à 4 fois plus grande que l'écoulement minimum; et les centrales thermiques etaient construites sous le principe de suppléer en premier lieu l'énergie hydraulique pendant la période de la pauvreté de l'eau. La raison d'adopter, pour le système de la production de l'énergie électrique au Japon, ce principe de prendre l'énergie hydraulique comme l'énergie principale et l'énergie thermique comme l'énergie supplementaire, est due premièrement au fait que les ressources du combustible telles que le charbon, l'huile, etc., sont pauvres au Japon, tandis que ce pays est relativement favorisé des ressources hydrauliques, et deuxiemement au fait que ce principe de l'exploitation de l'energie electrique est favorable au point de vue économique de la production electrique. En un mot, on etudiait au Japon de trouver le systeme le plus économique de l'utilisation combinée de l'energie hydraulique et de l'énergie thermique.

Dans cette thèse, on fait l'étude comparative du système de l'utilisation combinée de ces deux énergies: lorsqu'on combine la centrale hydraulique et la centrale thermique, on annexe l'etang régulateur à la centrale hydraulique; pendant la période de la pauvreté de l'eau, l'énergie hydraulique est fournie pour faire face au sommet, et l'énergie thermique est fournie pour la basse charge; par cette façon, en même temps que l'on diminue la capacité d'installation de la centrale thermique qui est supplementaire, on augmente l'efficacite de la production electrique, en augmentant son facteur de charge; pendant la periode de l'abondance de l'eau, en utilisant conjointement l'energie thermique pour faire face au sommet, on diminue l'ecoulement inefficace de la production hydraulique. Pour conclure, c'est le systeme le plus économique de la production de l'energie electrique; d'ailleurs, quoiqu'il soit le plus economique de fixer la decharge maximum a peu pres 1.5 à 2 fois plus grande que l'ecoulement minimum, quand on eleve ces chiffres à 3 a 4 fois, non seulement le prix de revient de la production de l'énergie electrique n'augmente presque pas, mais on peut s'attendre ainsi a l'utilisation efficace des ressources hydrauliques, ce que conclut cette thèse.

RESUMO

As usinas hidroelétricas do Japão, desde antes da guerra, adotaram o principio de fixar sua descarga maxima em 3 a 4 vezes mais que a vazão minima. Por outro lado, as usinas termoelétricas foram construidas baseadas no principio de suprir, em primeiro lugar, a energia hidráulica durante o periodo das secas. A razão de se adotar, para o sistema da produção de energia elétrica no Japão, esse principio de tomar a energia hidráulica como energia principal e a energia térmica como suplementar, resulta, primeiramente, do fato de recursos combustiveis tais como carvão, oleo etc., serem escassos no Japão, enquanto o mesmo paiso se vê relativamente favorecido por recursos hidráulicos, e em segundo lugar do fato de que o principio de exploração de energia elétrica e favoravel sob o ponto de vista econômico da produção eletrica. Em suma, estudou-se, no Japão, o meio de se encontrar o sistema mais econômico do emprego combinado da energia hidráulica e da energia térmica.

Nessa monografia se faz o estudo comparado do sistema do emprégo combinado dessas duas energias: desde que se combina a central hidráulica com a térmica, anexa-se a bacia reguladora a central hidráulica durante o periodo das sêcas, a energia hidráulica e fornecida para enfrentar o máximo, e a energia térmica e fornecida para a carga baixa; e assim, ao mesmo tempo que se diminui a capacidade de instalação da central térmica que e suplementar, aumenta-se a eficiência da produção elétrica,

aumentando seu fator de carga; durante o período de abundância de água, utilizando-se, conjuntamente, a energia térmica para enfrentar o máximo, diminui-se a vazão ineficaz da produção hidráulica. Em conclusão, é o sistema mais econômico da produção de energia elétrica; aliás, conquanto seja mais econômico fixar a descarga máxima em mais ou menos 1,5 a 2 vêzes mais que a vazão mínima, quando se aumentam essas cifras a 3 e 4 vêzes, não só o preço de custo da produção de energia elétrica quase não aumenta, como se pode confiar, assim, no emprêgo eficaz dos recursos hidráulicos, e com o que se conclui essa monografia.

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REUNIÃO PARCIAL
SECTIONAL MEETING
Rio de Janeiro - 1954

NODA (1)
Japan

THE RECENT STUDY ON THE JOINT UTILIZATION OF HYDRO AND THERMAL ELECTRIC POWER IN JAPAN

By JUNJI NODA
JAPANESE NATIONAL COMMITTEE

1 FOREWORD

Although the seasonal stream flow variations of the rivers in Japan is great, because of the reason that the construction of reservoirs capable of controlling such flow is not easy technically and economically, it has become the basic principle to work out the increment of the supplying capability against the increment of the demand power, by the combination of hydro power and supplemental thermal power.

In such a case, the problem lies in the point that how far in the extent should the combination of hydro and thermal power be, in order to have the composite electric power original cost of the power source complying to a predetermined given load, set minimum. In regard to the result of the study of the pre-war years in Japan a report has been submitted to this Sectional Meeting, prepared jointly by Mr. Toshio Yoshioka and Mr. Kyuichi Yamazaki under the title of "The Joint Utilization of Hydro and Thermal Electric Power in Japan" (hereafter, to be termed as the Yoshioka-Yamazaki Thesis), however, in this paper, I would like to report the result studied from a different angle, that is, taking the new post-war conditions into account.

2 REGARDING THE EXPRESSION OF LOAD

The load observed from the generating end of the Kansai Electric Power Co. on a typical day of May and December, 1952, is as given in the right side of Fig. 1 (a) and (b). However, the load duration curve, rearranged in the order of it's magnitude is shown in the left side of this same diagram. This is approximately close to the straight line connected

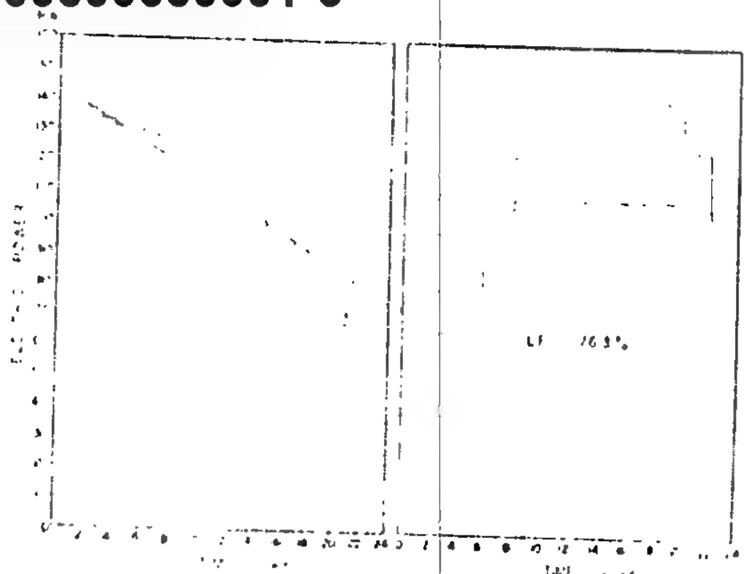

Fig. 1 (b) — Generation end load of Kansai Electric Power Co.
On Dec. 17 (Wednesday), 1952

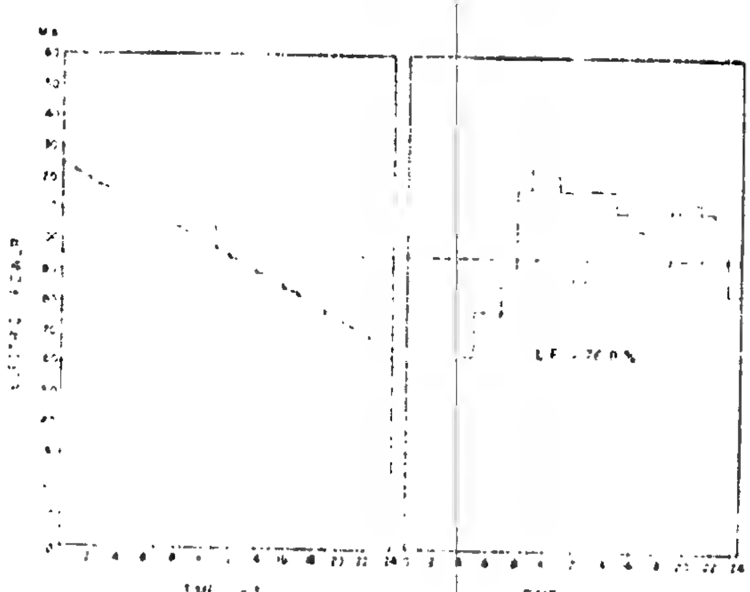

Fig. 1 (4) — Generation end load of Kansai Electric Power Co.
On May 21 (Wednesday), 1952

between the maximum electric power and the average electric power in [illegible] therefore, in this paper, for the convenience sake of the computation, we would like to represent this daily load curve by the straight line having a certain slope against the time axis as shown in Fig. 2. Setting P_{lm} as the maximum electric power and

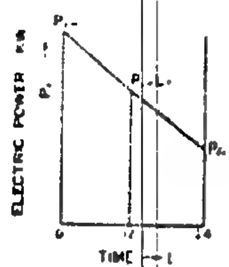

Fig. 2 — Daily load duration curve

L_n as the load factor, the equation for the daily load curve could be given by the formula (1)

$$P_t = P_{lm}\left\{1 - \frac{1 - L_n}{12} t\right\} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Hereupon setting both the maximum electric power and the load factor constant throughout the year, for the sake of simplification, the electric power energy of the load shall be $P_{lm} \times L_n \times 8760$ KWH. As the maximum electric power and the load factor, actually varies considerably day by day, at least it is necessary to study taking the monthly variation into account, after arbitrarily having performed the computation under the above mentioned assumption.

3. REGARDING THE REPRESENTATION OF THE HYDRO POWER SUPPLYING CAPABILITY

Furthermore, in regard to the hydro power supplying capability, if expressing the hydro power generating capability based on the natural stream flow by the duration curve, it could be considered approximately as a straight line for the group of hydro power sources including the numerous power plants which have different river systems. Fig. 3 is the stream flow curve for the system comprising about 130 hydro power plants,

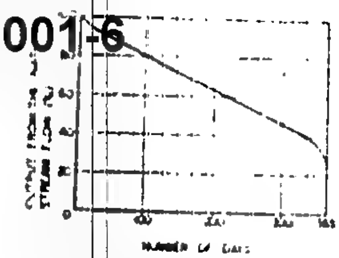

Fig. 3 — Examples of stream flow curve converted in generating output, and given in percentage against the maximum output

with the daily records covering for ten years, arranged in the order of their magnitude, and plotted by taking the average value of ten records in order.

In Fig. 4, setting the ratio of generating capability during the worst

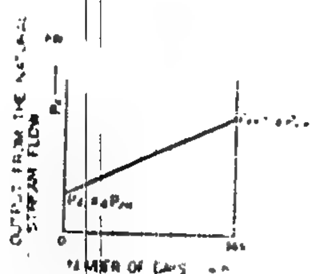

Fig. 4 — Stream flow curve

condition of the poor water season P_{sm} against the maximum electric power of the load P_{lm} as k, and setting the number of times of the maximum generating capability P_{hm} against P_h as j, then the equation representing the stream flow curve could be given by the formula (2)

$$P_h = k P_{lm}\left(1 + \frac{j-1}{365} n\right) \cdots \cdots \cdots (2)$$

4. THE REPRESENTATION OF THE RELATION BETWEEN THE LOAD AND THE HYDRO POWER SUPPLYING CAPABILITY, AS WELL AS THE DETERMINATION OF THE SUPPLEMENTAL THERMAL POWER ELECTRIC ENERGY.

We would like to explain the relation between the load and the hydro power supplying capability by the three dimension diagram setting the x axis as the number of hours per day, y axis as the number of days, and z axis as the electric power.

In case of the hydro power plants having no pondage and being [illegible] the natural stream flow as it is, the relation of the load and the hydro power supplying capability could be given as in Fig. 5. In this said diagram, the supplemental thermal power elec-

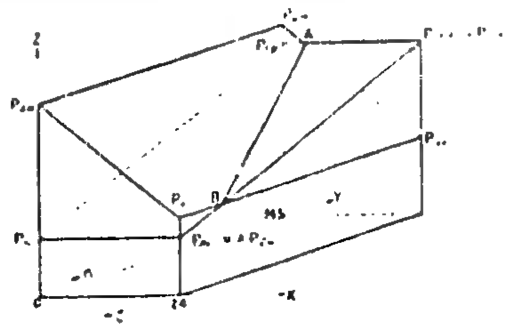

Fig. 5 — The relation between the hydro power with no pondage and the load

tric energy required could be represented by the volume of the solid sandwiched between the parallel plane P_{lm}, P_{hm}, A and P_{l0}, P_{lm}, P_{h0} however this could be obtained by the computation formula of Table 1, if maximum power P_{lm}, daily load factor L_n, the number of times j of the maximum against the minimum of the stream flow curve P_{h0}, P_{hm}, the ratio k of P_{h0} against P_{lm} are given. This is somewhat near to the system between (A) and (D) of YOSHIOKA YAMAZAKI thesis 2.1.

TABLE 1

	$k \leq 2L_n - 1$ $(P_{h0} \leq P_{l0})$	$k \geq 2L_n - 1$ $(P_{h0} \geq P_{l0})$
$jk \geq 1$ $(P_{hm} \geq P_{lm})$	$\frac{5840(1-L_n)^2 + 4380(1-k)(2L_n-k-1)}{(j-1)k} P_{lm}$	$\frac{730(1-k)^3}{k(1-L_n)(j-1)} P_{lm}$
$1 \geq jk \geq 2L_n - 1$ $(P_{lm} \geq P_{hm} \geq P_{l0})$	$\frac{730\{8(1-L_n)^3 - (1-jk)^3\}}{k(1-L_n)^2(j-1)} P_{lm} + \frac{4380(1-k)(2L_n-k-1)}{k(j-1)} P_{lm}$	$\frac{730\{(1-k)^3 - (1-jk)^3\}}{k(1-L_n)(j-1)} P_{lm}$
$jk \leq 2L_n - 1$ $(P_{hm} \leq P_{l0})$	$8760(L_n - \frac{1+k}{2}) P_{lm}$	

Next, if, the hydro power plants have pondage sufficient to control the daily natural stream flow against the load variation of a respective day, and if the thermal power generation is to be carried in the most ideal manner, in order to have it operated with the load factor as high as possible, the relation between the load and the hydro power supplying

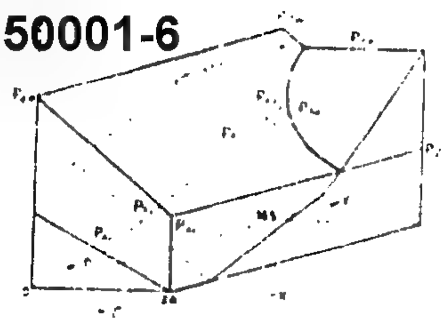

Fig. 6 — Relation between hydro power with pondage and load

capability could be given as in Fig. 6. In such a case, the supplemental thermal power electric energy could be obtained by the computation formula of Table 2. This is somewhat near to the system between (B) and (E) of YOSHIOKA-YAMAZAKI thesis 2.1

TABLE 2

$jk \leq 1$	$k \geq L_n$	0
	$k \leq L_n$	$\frac{4360(L_n-k)^2}{k(j-1)}P_{fm}$
$1 \leq jk \leq 2L_n-1$	$j \leq 2, k(2-j) \geq 2L_n-1$	$\frac{2190(1-jk)^2}{k(j-1)}P_{fm} \quad \log\frac{1-L_n}{1-jk+k-L_n}$
	for other cases,	$\frac{4380}{k(j-1)}\left\{(L_n-k)^2-\frac{1}{4}(1-jk)^2+\frac{(1-jk)^2}{2}\log\frac{2(1-L_n)}{1-jk}\right\}P_{fm}$
$jk \geq 2L_n-1$		$8760\left(L_n-\frac{1+j}{2}k\right)P_{fm}$

The ratio j between P_{hm} and P_{fm} differs depending on how many times the maximum discharge of hydro power plant is taken against the poor water season flow, and it covers considerably a wide range in regard to the individual power plant in existence. However, if checking on the stream flow curve of the system with a large number of power plants put together, it is roughly in the range of j = 2 – 1.

In the case of YOSHIOKA-YAMAZAKI thesis, the conclusion is made that the minimum original cost could be obtained in the case of j = 1.5 – 2.0. However, if assuming that the construction unit cost is to be inversely proportional to $\frac{1}{3}$, $\frac{1}{4}$ and $\frac{1}{8}$ power of the maxi-

[illegible] me as that of 2 of Yoshioka-Yamazaki [illegible] approximately the same conclusion even at the present. Nevertheless, the hydro sites to be developed actually are restricted, and the limitation of the supplying capability increasable by the power plants which have adopted low discharge is obliged to be of low figure. Then, the problem lies unsettled on how much the j should be set, however, arbitrarily in this paper, we have decided to discuss under the premise that we would have j = 3 for the stream flow curve of a great number of hydro sites combined. Now, if we are to consider for the case in which $\frac{P_{ho}}{P_{lm}} = k$ is to be changed variously, with the load factor $L_a = 70\%$, and maximum electric power $P_{lm} = 100$ Mw set constant throughout the year, the allotment amount of hydro and thermal power generation is as given in Fig. 7.

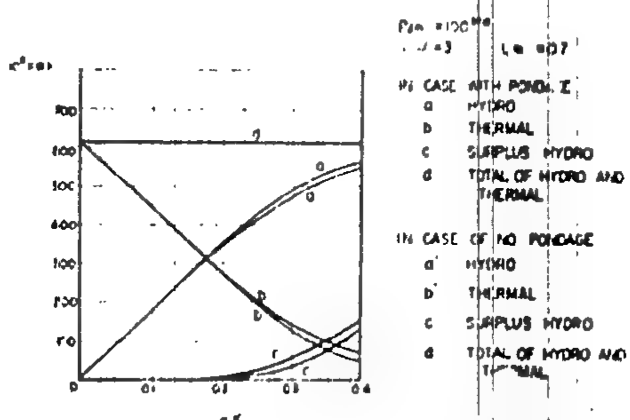

Fig. 7 — The allotment of hydro and thermal power generation

5 THE COMPOSITE ELECTRIC POWER ORIGINAL COST FOR THE VARIOUS COMBINATIONS OF HYDRO AND THERMAL POWER.

Setting the construction unit cost per Kw for hydro power as 100,000 yen ($277.77), for thermal power as 60,000 yen ($166.66), interest as 10%, the maximum thermal efficiency of the thermal power plant as 27%, coal price as 6,000 yen/ton ($16.666) (dried coal heating value 5,500 Kcal/Kg, rate of moisture content 7%), we would like to obtain the composite electric power original cost, in case of changing $\frac{P_{ho}}{P_{lm}} = k$ value,

variously. Generally, the thermal power plants are to be installed in the [illegible] demand, however the hydro generating sites are remotely located, therefore, as for the original cost of hydro electric power which is to be combined with the original cost of thermal electric power, we have to take into account the power transmission and transformation cost as far as the demand center, together with the power plant expenditure. In addition, we should compute on the respective case of the power transmission loss for the hydro and thermal power, and should obtain the original cost per unit electric power energy at the secondary side bus of the receiving end substation. However, in this paper, conceiving that the rate of power transmission loss of the hydro power is to be approximately equal to the rate of station use thermal electric power, for the convenience of computation, we would like to compare the original cost per unit of generating end electric energy including the station use electric power of the thermal power, differing with the YOSHIOKA-YAMAZAKI thesis 2. Setting the power transmission line distance as 250 Km, voltage 275 Kv, 300,000 KVA for the receiving end substation, and the total construction cost of these as 7,100 million yen, the required expenditures for such is to be splitted in the ratio of the maximum generating electric power of the hydro power and the power transmission capacity 300,000 Kw. (at present 360 yen = 1 dollar). If changing the value of k variously, the original cost per unit generation energy is as given in Fig. 8.

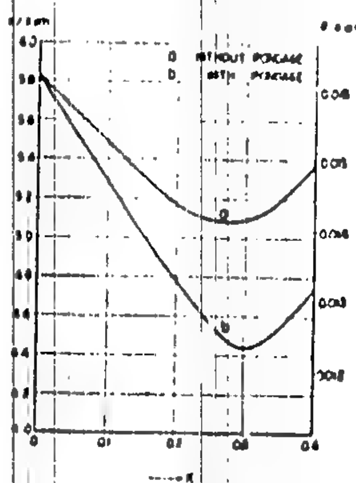

Fig. 8 (a) — For the case the load being constant throughout the year (100 MW)

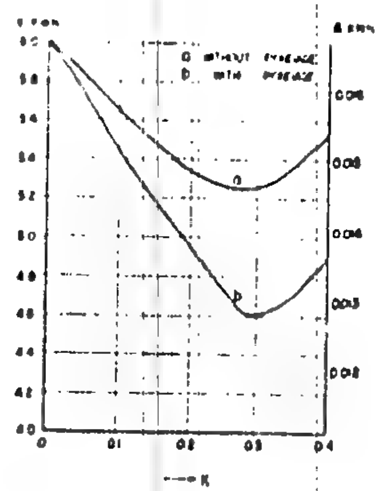

Fig. 8 (b) — Modified case, taking the monthly variation into account

Obviously, from this diagram, the case k = 0.3 is the most economical. This is that, against the load of the maximum electric power of

100 Mw, load factor of 70%, it means that the composite electric power [illegible] for the combination of hydro power without pondage as 90,000 Kw, thermal power as 70,000 Kw, and hydro power with pondage as 90,000 Kw and thermal power 40,000 Kw. The relation of the load and the hydro and thermal power generation for the latter case is given in Fig. 9. The above discussion is based on the

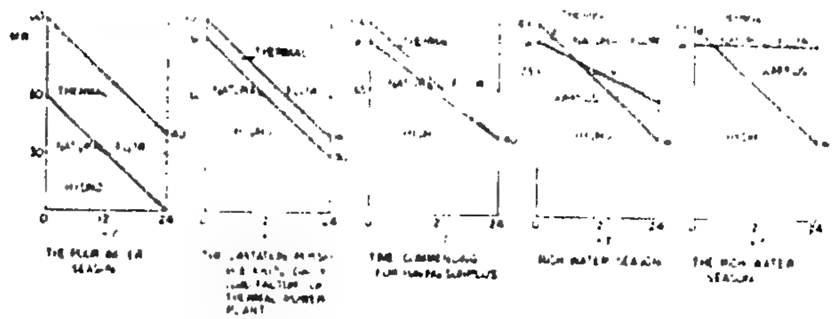

Fig. 9 — Load curve of P_m = 100 MW L_f = 0.7 j = 3.0 K = 0.1 for the case of hydro power plant with pondage

idea of setting the load constant and no changes throughout the year, however, there is a considerable variation seasonally even for the firm electric power.

Generally, as the load during the winter dry season has the tendency rather to be increased, as far as this point is concerned, there is an imperfection in setting the condition. Hence, regarding the annual average maximum power of 100,000 Kw, and annual average load factor of 70%, as the monthly variation is given in Table 3, we would like to assume 63% for the annual load factor, setting as a close resemblance to the load variation which could be forecasted several years after in the Kansai Electric Power Co.

We would like to show the stream flow curve of 90,000 Kw of hydro power, given as the most economical combination of hydro and thermal power as mentioned above, in Fig. 10 with monthly breakdown, setting up as a close resemblance to the stream flow curve, obtained by averaging each ten values of records which was based for Fig. 3, in the order of their magnitude selected from the 300 or 310 daily records covering for the past ten years. However, representing the daily load by the peak load, average load and the midnight load, and if we are to obtain the supplemental thermal power electric energy for the case of using the pondage most effectively against the above mentioned respective load, the result is not so great compared with that of the former, the difference being within 2%. Consequently, as far as the required electric energy of supplemental power is concerned, it became clear that approximately

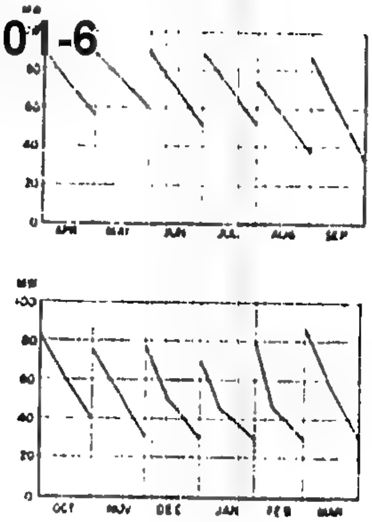

Fig. 10 — Monthly hydro power stream flow curve

a precise figure could be obtained, it computed by following the previously mentioned computation. However, for the maximum output of the required supplemental thermal pow r, the load is 110,000 Kw (P_{1m}) during the poorest water season against the annual average maximum of 100,000 Kw (P'_{1m}), therefore, it is necessary to modify the magnitude of the thermal power in the most economical combination of hydro and thermal power obtained previously. Even though after performing such modification, it still makes no difference when this combination is the most economical for the case that the monthly load variation is taken into account, as given in Fig. 8 b. In other words, against the load of the annual average maximum 100,000 Kw (P'_{1m}), the most economical combination of hydro and thermal power is hydro power 90,000 Kw, thermal power 50,000 Kw. This load becomes 110,000 Kw (P_{1m}) in December and in February, the annual load factor being 63% and the load factor of supplemental thermal power is less than 28%.

6. RESERVOIR TYPE HYDRO POWER, AND ITS INSTALLATION AND THERMAL POWER INSTALLATION AS REPLENISHING ELECTRIC POWER SOURCE

As mentioned above, we have obtained the most economical combination for hydro and thermal power against the given load arbitrarily, however for the replacement of supplemental thermal power installation, the reservoir type hydro power and pumping system hydro power installation could be conceived. Fig. 11 is the diagram comparing the hydro

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and thermal electric power original cost against the same installation load [illegible] factor becomes high, we could see that hydro power is exceedingly cheaper than the thermal power.

This is due to the fact that it's effect at high load factor becomes great, because of the high cost of coal. Furthermore, under low load factor, the effect of the fixed expense becomes large the result being the hydro power with high construction cost becomes more expensive than the thermal power.

For the load factor of the thermal power under the most economical hydro and thermal power combination obtained in the previous chapter, the electric power original cost of the hydro and thermal power becomes very close, and the electric power original cost of the hydro will become rather more expensive depending on the construction unit cost.

Even in the reservoir type hydro power station, since there is a portion of similar nature with that of the ordinary run-of-river type hydro power station controlled by the natural stream flow, precisely speaking, a comparison study with the thermal power should be made, after taken these into account. However, regarding to that which having 28% installation load factor and of which entire generating power could be considered as a replacement for thermal power, and if the construction cost per Kw are as much as:

49 yen for the coal price of 6,000 yen per ton
45 yen for the coal price of 5,000 yen per ton

then, we could lower the composite electric power original cost in further

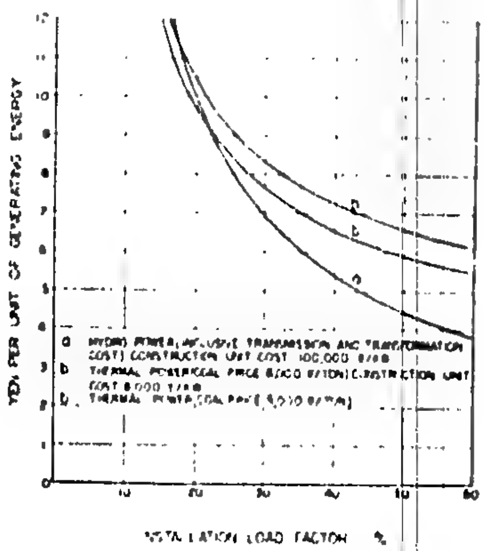

Fig. 11 — The relation of installation load factor and the hydro and thermal electric power original cost

extent, by utilizing the pondage type hydro power generating stations.

TABLE 3

Months	Average electric power	Load factor	Average maximum power	Midnight average electric power
April	71.0 Mw	73%	97.3 Mw	44.7 Mw
May	68.2	74	92.2	44.2
June	65.7	74	88.8	42.6
July	67.1	73	91.9	42.3
Aug.	65.2	72	90.5	39.9
Sept.	66.9	71	94.2	43.1
Oct.	70.9	69	102.7	43.1
Nov.	72.5	68	106.6	47.0
Dec.	74.0	66.5	111.2	46.1
Jan.	72.3	67	107.9	45.6
Feb.	74.7	68	110.0	48.2
Mar.	72.2	68	106.2	46.7
Annual average	70.0	70	100.0	

7. CONCLUSION

In short, as mentioned previously, in the case of $\frac{P_{b1}}{P_{b2}} \fallingdotseq 3.9$,

in the stream flow curve of hydro power the maximum load power P_{bm} = 110 Mw (annual average maximum P'_{bm} = 100 Mw), annual load factor 63% (annual average load factor 70%), the conclusion is that, against the hydro power 90 Mw with pondage, 50 Mw thermal power of the poor water season replenishment, as well as of the rich water season and heavy load period, should be jointly utilized, furthermore, if there is a reservoir type or pumping type hydro power plant being more economical than the abovementioned supplemental thermal power, then such hydro station should be constructed for the replacement of thermal power. However, in this paper, the study was made for a predetermined firm power as the object. It is conceivable that a further extensive study is necessary hereafter for the case of the so-called special power which is to be supplied only during the rich water season, as well as for the consideration of the load and supplying capability being superimposed on the existings.

SUMMARY

This paper is the result of the study describing how to minimize the overall generation cost by arranging the combinations of the hydro and thermal power generating facilities, in case of complying with the required firm power load by jointly utilizing the hydro power generated under the natural stream flow and the supplemental thermal power.

In this study, assuming the duration curve of the load and natural stream flow to be in the shape of straight line, we have computed the overall generation original cost of hydro and thermal power, varying in accordance with the various value of k, which is the ratio of the hydro generating power due to the natural flow during the poorest water season against the maximum electric power of the load. The conclusion is that the generation original cost becomes the minimum when $k = 0.3$.

In other words, assuming that the maximum electric power load is 100 MW, being constant throughout the year, the installation which gives the minimum value of the generation original cost is, in case of without pondage for the hydro plant, we have 90 MW for hydro and 70 MW for thermal, while for the case of with pondage for the hydro plant, we have 90 MW for hydro and 10 MW for thermal. Actually the load during the poor water season rather becomes large, and assuming this load is to be 110 MW, we have 90 MW for hydro and 50 MW for thermal, in case of pondage being provided for the hydro plant. However, this conclusion is conceivable for approval providing that the economical condition does not change considerably in a large extent.

RÉSUMÉ

Cette thèse étudie quelle combinaison on doit choisir entre l'installation électrique de l'énergie hydraulique et celle de l'énergie thermique, pour obtenir le minimum de la somme des prix de revient de toutes les énergies, quand on fait face à la charge électrique constante donnée, en combinant l'énergie hydraulique par l'écoulement naturel et l'énergie thermique qui est supplementaire.

Dans cette étude, on a suppose que la courbe de durée de la charge et celle de l'écoulement naturel soient lignes droites; et on a calculé la somme des prix de revient de toutes les énergies hydrauliques et thermiques, correspondant aux différentes valeurs de (k), rapport entre l'énergie hydraulique par l'écoulement naturel pendant la période de la plus grande pauvreté de l'eau et la charge maximum; et on a conclu qu'en cas de $k = 0.3$, cette somme montre le minimum.

A un autre mot, quand la charge maximum est constante et de 100 MW pendant toute l'année, pour obtenir le minimum de la somme des prix de revient, l'installation hydraulique sans l'étang régulateur doit être 90 MW contre 70 MW de l'installation thermique, et l'installa

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tion hydraulique avec l'étang régulateur doit être 90 MW contre 10 MW [illegible] l'on tient compte de ce qu'en réalité, la charge monte la valeur élevée plutôt pendant la période de la pauvreté de l'eau, et atteint à 110 MW, l'installation hydraulique avec l'étang régulateur doit être 90 MW contre 50 MW de l'installation thermique.

Cette conclusion peut être valable si les conditions économiques ne présentent pas une différence assez grande.

Resumo

Esta monografia é o resultado de um estudo pelo qual se mostra como reduzir ao mínimo o custo de produção de energia pela combinação das facilidades geradoras da energia hidráulica e da energia térmica, obedecendo-se à carga constante dada, mediante a utilização conjunta da produção de energia hidráulica pela vazão natural e da energia térmica suplementar.

Nesse estudo, supondo-se que a curva de duração da carga e a vazão natural figurem em linha reta, calculou-se o custo original de produção de energia hidráulica e térmica, variando de acôrdo com os diversos valores de k, o qual é a relação entre a energia hidráulica pela vazão natural durante a época de maior escassez de água e a carga máxima de energia elétrica. E a conclusão é que o custo original de produção torna-se o mínimo quando se tem k = 0,3.

Em outras palavras, supondo-se que o máximo de carga de energia elétrica seja 100 MW e constante durante todo o ano, a instalação que dá o preço mínimo para o custo original de produção, sem acumulação reguladora para a instalação hidráulica, deve ser de 90 MW contra 70 MW para a instalação térmica, enquanto que para o caso de instalação hidráulica com acumulação reguladora, temos 90 MW contra 10W para a instalação témica. Atualmente a carga durante a época de escassez de água torna-se um tanto elevada, e supondo-se que seja 110 MW, temos 90 MW para a instalação hidráulica e 50 MW para a térmica, no caso da instalação hidráulica ser provida de acumulação reguladora. De qulquer maneira, esta conclusão pode ser considerada válida desde que as condições econômicas não apresentem alterações demasiadamente grandes.

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Título
Assunto 2 2

MIYAMOTO (S.)
Japão

THE INFLUENCE OF THE CLIMATIC FEATURES PECULIAR TO TROPICAL AND SUB-TROPICAL REGIONS ON THE DESIGN, CONSTRUCTION AND TREATMENT OF THE ELECTRICAL EQUIPMENT

By SHIGENARI MIYAMOTO
Member of the Technical Committee of the Japan Electric Machinery Association
JAPANESE NATIONAL COMMITTEE

1. *Special Considerations to be Taken for Electrical Equipment Used in Tropical and Sub-Tropical Regions*

Electric equipment to be used in tropical and sub-tropical regions are generally subjected to high temperature and high humidity and in some territories the temperature and the humidity make a drastic change in the course of day. The equipment should be of such a design and construction that can withstand those severe condition of the climatic effect most effectively.

In fact, the insulation of the electric equipment receives most conspicuous effect from the above conditions, for the insulating material not only reduces the insulating strength due to absorbed moisture but deteriorates losing the strength by the condensation of moisture or water drop and moulds gathered on its surface. And the absorption of moisture and the gathering of moulds not alone mean the temporal decrease of the insulating strength but in many cases lead to expansion, softening, deformation, and decomposition of the material itself, shortening the service life of the electric equipment.

On the other hand, moisture condensed on the metal part makes [illegible] the poor contact, deeper corrosion, contamination, etc.

In case of oil-immersed equipment, the absorption of water into oil, the oxidation of oil and the generation of sludge are accelerated in the above mentioned climate.

The measures for preventing all of these troubles should be the effective method in keeping away first the moisture condensing on the equipment surface, secondly the permeation of moisture into the insulation and in the third place the gathering of moulds.

2. *Experiences and Capability the Japanese Electric Manufacturers have Gained in the Manufacture of Electrical Equipment for Tropical and Subtropical Regions*

In Japan, both manufacturers and users of electric machines and apparatus have been thoroughly experienced in harmful effects on their machines caused by the peculiar climatic conditions, i.e. high temperature accompanied by high humidity in summer season from June to August.

In early days, they had considerable troubles due to this cause, which led them to improve the old design and construction, and finally very satisfactory conclusion has been achieved.

Fig. 1 shows the comparison of the relative humidity (above) and the temperature (below) between in Tokyo (solid line) and in London (dotted line), recorded for the period of one year. As can be seen from the Figure, the relative humidity in Tokyo increases with the tempe-

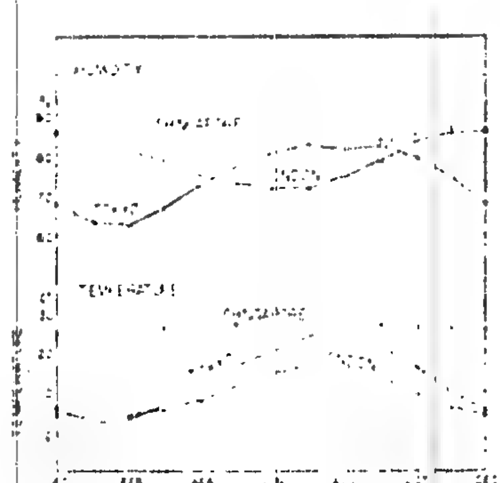

Fig. 1

rature in summer, making comparison with those in London which draw [illegible] the relative humidity increases in winter while decreasing in high temperature period of summer. Because of such tendency of the climatic change, although there are no conspicuous difference in the annual average humidity and temperature between Japan and Europe or the U. S. A., Japan bears a peculiar aspect in high moisture content in the air and growth of mould in the wet season. Any foreigner unfortunately visiting Japan in the rainy season in summer should have had his own experience in the depressing, steamy weather, and observing rapid growth of mould on almost everything. Dr Miyabe, professor of the Waseda University in Tokyo, who has been devoted for many years to the problem of the moisture absorption by insulating materials, explains as to the relation between moisture content and humidity and temperature as follows:

In general, moisture makes its way to the place where the humidity pressure (water vapor pressure) is lower. When the humidity of the surrounding air of any insulation material increases and the humidity pressure exceeds that of moisture in the insulating material structure, the moisture in the air begins to intrude into the material through surface film, continuing permeation into the interior of lower humidity pressure. As the humidity pressure inside the insulating material rises according to moisture absorption the process slows down and ceases when the humidity pressures within the outside the material come in a state of equilibrium.

In as much as the equilibrium moisture content in this case shows lower value as the temperature of the surrounding air is highter no assertion could be made for the bad effect of the high temperature if the above value alone were considered. But the problem is not in the equilibrium moisture content at the time when the equilibrium has been reached but in the rate of increase of moisture content before the instant of equilibrium.

The increase of humidity around an insulating material causes moisture diffusion and increase of moisture content inside the insulating material

If moisture conductivity be λ, moisture capacity per unit volume be c, and moisture content at any point within the insulating material be m, the relation among them is expressed as follws.

$$\frac{dm}{dt} = \frac{\lambda}{c}\left(\frac{\partial^2 m}{\partial x^2} + \frac{\partial^2 m}{\partial y^2} + \frac{\partial^2 m}{\partial z^2}\right)$$

Hence, in the high temperature the decrease of c is greater than λ, the rate of increase of the moisture content is far more rapid than in the case of low temperatures. Therefore, the simultaneous concurrence

of high temperature and high humidity causes high average moisture [illegible]als. Even if the surface of insulation material is covered with moisture-preventive film, time constant of moisture permeation is in proportion to c, so that the time rate of the increase of moisture content is larger when the temperature is higher. In the summer season in Japan, such a high humidity over 80% lasts for about three months in the temperature around 25°C. In this drastic period, any insulation on the electric equipment cannot be free from a considerable degree of moisture absorption and the growth of moulds on its moist surface, unless it is entirely proofed against moisture.

The manufacturers of electric machine and apparatus in Japan have accumulated wide experiences and researches in this respect, and now have succeeded in establishing a recognized practice, endorsed by achievements, in the design and the treatment of the products for southern markets including Formosa, Okinawa, Hainantao, India, Pakistan, Burma, Thailand, Indonesia, South Sea Islands, South American Countries and others.

As mentioned above, there is no appreciable difference in severity of moisture absorption between Japan and tropical and subtropical regions. However, to make sure the Japanese product's qualification for the international standard level a committee to investigate data and figures of tropical condition was organized in 1942 by the Japanese Institute of Electrical Engineers. And a part of its activity was materialized soon later as the standard model test-code for tropical-bound electric equipment, which have been adopted as the Japanese Industrial Standards, later, (partly revised in 1952). This standard depended such for the basic framing on the German Standard VDE No. 0475 and combined a number of our experimental results and several regional conditions peculiar to Japan.

This test code comprises eleven articles and provides in detail the conditions and methods of long term (for assumption of life) and short term (to detect superficial faults) testings in relation to high temperature high humidity test, intermittent high temperature high humidity test, high temperature test, dewdrop test, precipitous temperature changing test, dry, high temperature and sunlight exposure test, mould test, and sea mist test.

Although the space cannot afford the introduction of the whole test, to mention the gist, the high temperature high humidity test is provided to be carried out inside the constant temperature and humidity tank maintained at the temperature of 40 ± 1°C and the relative humidity of 90% ± 3%. These values are adopted on reference to the actual measurement in the South-East Asian Territories and in ship's hold of south sea liners. The period of testing ranges from four weeks to more than three months.

The intermittent high temperature high humidity test is to be con- [illegible] equipment to be tested is kept under the above-mentioned conditions for eight hours, then cut off the heat source to cool down to the room temperature and maintained in that state for sixteen hours. After that period the temperature and the humidity are restored to 40°C ± 1°C and 90% ± 5% respectively. This procedure is repeated several times. This procedure was adopted mostly in connection with the easy performance of the test in laboratory.

The high temperature test should be effected with constant temperature tank under relative humidity less than 75%, at three different temperature, 40° ± 2°C, 55 ± 3°C, and 70 ± 3°C, as standard.

The dewdrop test uses a low temperature tank kept at 20 ± 5°C with the relative humidity less than 70%. The test material is placed in it and when the temperature of the material is proved not to differ more than 3°C at its internal part with the tank temperature, material is rapidly moved to the aforementioned high temperature high humidity tank to examine the dewdrops condensing on its surface.

After the inside temperature of the material has reached the tank temperature with tolerance of ± 3°C, the material is returned into the low temperature tank. This procedure is repeated 50 times in case of short term testing and 200 times in long term testing. This test serves to examine the electro-chemical action of electrolytic liquid produced by dewdrops effect of locally consisted cell, producing of metal-corrosive substance by varnish, rubber and organic oils, etc. under the wet and high temperature conditions.

The dry high temperature and sunlight exposure test is conducted under the condition similar to the solar radiation, and such condition is accomplished by placing a mercury arc lamp, whose wave length is filtered to cut off below 280 mμ, at such a position that its radiation energy becomes 0.0042 watt/cm² and an infra-red lamp on the same side. The infra-red lamp is used to supplement long wave radiation of sunlight, and is adjusted to give in combination with the mercury lamp, the total radiation energy of 0.084 watt/cm². The room temperature is kept at 55 ± 3°C. The testing period ranges from a week to more than one month.

The mould test stipulates the culture of moulds for the periods of a week in short-term test and more than one month in case of long term test in the surroundings of 30 ± 1°C (this range of the temperature being most favourable for the growth of fungi) and 90% ± 5% relative humidity. The cultivation is to be performed in such a way that thallophyta such as Aspergillusnigar, Aspergillusflavas, Penicillium luteum, Trichoderma T-1, etc. are placed on a water-soaked crumb filled to 5mm thick in Petrie's dish and the dishes are placed in the above-mentioned surroundings at the rate of one dish per 1/2 m³ of the space.

The sea mist test is to be carried out in a totally enclosed room [illegible] which 5% brine is sprayed once an hour at the rate of 30 cc per 1 m³ of the room space. The test should continue three days in the short term test and more than four weeks in the long term test.

Although the above are the test preparations requisite for providing similar climatic conditions to those of tropical territories, every tropical district does not combine all of such conditions. Hence the tests in some necessary categories out of the above will suffice each case.

3. *Some Examples of Considerations Taken for Design, Construction and Treatment of Electric Equipment Destined to Tropical and Sub-Tropical Regions.*

a. Measures taken for dry insulations of generators, electric motors and dry type transformers.

The class A insulation to be used in general for low tension, small capacity equipment consists basically of cellulose material which retains moisture-absorptive nature and is short of heat-resistance. And the one treated with varnish of natural oil origin is liable to nourish moulds, making the equipment quite unsuitable for the tropical service. This is remedied considerably, however, by extracting in warm water dextrines and multi-saccharides from cotton cloth tapes used in the insulation or by substituting cotton cloth with silk. Such procedure will restrain the growth of moulds.

A larger freedom from the moisture absorption can be expected by coating a thick varnish film on the insulation surface. The varnish film for this purpose should be of organic varnish of phenolic base or alkyd base and the film formation should be done by four or five repetitions of dipping of the equipment in the varnish and drying. It is proved to be effective to give the protective coating thereon with the varnish of alkyd base containing inorganic pigment such as oxidized iron dust.

Needless to say, the replacement of the class A insulation with the class B insulation such as mica, glass, asbestos, etc. would give more satisfactory solution to the problem, heat-resistance being improved and bad effect of moisture absorption being mitigated when it is used with the above mentioned organic varnish and compound.

In case that the service condition proves to be severer, the use of the class H insulation is recommended, which com-

poses the treatment of inorganic insulations with silicone varnish ... the excellent chemical stability, heat-resistance and water-repelent.

Many a dry type transformer up to the voltage of 22 kV and the capacity of 500 KVA with this sort of insulation has already been in practical service in Japan, giving satisfactory results. This type of transformer is being taken into service in many cases in such places as building basement substations, coalmine galleries, etc. where constant fire hazard is threatening under bad conditions of high temperature and high humidity.

As regards the mould-preventive paints, extensive research work has been conducted in many laboratories and manufacturing companies, and some of chemical paint manufacturers have already succeeded in industrialization of the product.

The experiment results have revealed that mould's sporules could germinate when they had occupied more than 18% of the stroma surface and such condition could be fulfilled at the relative humidity of about 80%. The mould-preventive chemicals must be harmless to component materials of the electric apparatus when applied thereupon, let alone the strong, long-lasting effectiveness. Such amalgams as Phenyl Mercuric, Pyridyl Mercuric compounds, etc., for instance, are known as being very effective in mould-prevention and insect repelling job but their use is limited because of the corrosiveness for selenium rectifiers and the like. Also, copper compounds such as Copper and Quinolinolate cannot be applied in electric equipment which use rubber components.

Pentachlorophenol, Pentachlorophenol Sodium Salt, Prichlorophenol, Salicylanilide, etc., are some of the products that are testified experimentally to the general effectiveness and are on the Japanese market. Especially Salicylanilide is discriminated for its efficacy in the mould prevention of textiles and leathers. The efficacy test for the above chemicals and others is being conducted using Cladesporium Cellar, Cladosporium Fulvum, Cladosporium Herbarum, Dematium Chodat, and Dematium Pullulance, besides the four kinds of thallophyta aforementioned. The above chemicals have been proved to hamper or stunt the growth of these moulds when used in the density of from 1:5000 to 1:50000. One example of Pentachlorophenol application shows that the mould prevention can be achieved when the chemical is mixed in paint in the rate of 1 — 5% of non-volatile component and the paint is coated to more than 0.002" thick.

There are cases in the tropical that termite and other [illegible] serious damage to spare coils and the like. For their protection, the aforementioned amalgams have been used on the wrappings or packages of those apparatus to be stored.

b. Countermeasures taken for oil-immersed apparatus such as transformers, etc

In power transformers, reactors, instrument transformers, voltage regulators or any other apparatus using insulation oils, the deterioration of the oil is caused by its contact with high temperature, high humidity carrying air which leads to the oil's absorption of moisture, increase of acidity, sedimentation of sludge, etc. Hence, hermetic seal of oil tank or sealing of conservator with oil to shut off the open air and filling in of nitrogen gas are one of the most efective methods to prevent the oil deterioration. As nitrogen gas, being completely free from water content owing to its manufacturing process and inactive chemically, does not deteriorate oils.

Figs. 2 (a) and (b) show the construction of the oil-seal conservators widely in use in Japan. Fig. 2 (a) gives the arrangement which is featured by the convenience to select freely the shape and installing position of the conservator and

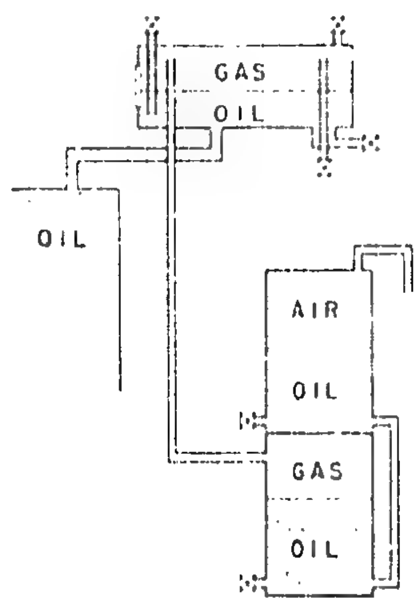

Fig. 2 (a)

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the sealing tank. In an instance of this type of design the [illegible] on horizontal type and placed under the radiator conveniently. The arrangement given in Fig. 2 (b) has been developed by Mr. Nakazawa on the similar principle to that of fuel gas tank. The bell type tank floating in the conservator goes up and down according to the expansion and con-

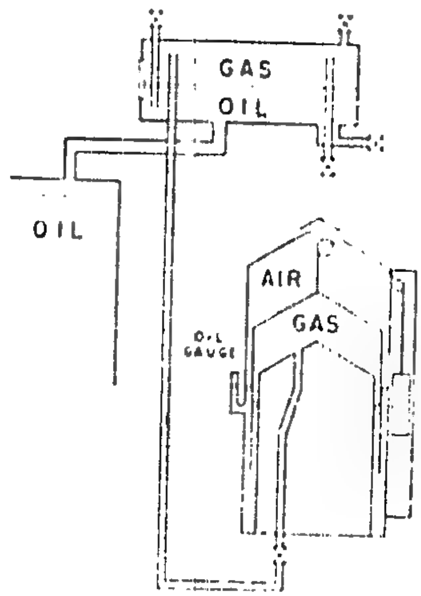

Fig. 2 (b)

traction of oil and gas, so the capacity of the sealing tank can be made much smaller than the capacity equivalent to the amount of the expansion and contraction, which allows to reduce the quantity of sealed oil to some extent.

Instead of sealing in nitrogen gas, such a method was used in some special cases, i.e. heating resistance of seathed-wire type whose circuit is automatically opened and closed by means of a thermal relay is installed inside the conservator, and by its function the temperature of the air inside the conservator is kept about 5°C higher than the outside temperature so that a current of the air flowing between inside and outside of the conservator does not cause the water vapour in the air to condensate on the inside surface of the conservator wall.

It is needless to mention that the insulation oil in use is to be of high-grade, properly refined from good quality crude

oil, and retains high stability of characteristics. When ne[illegible] [illegible] deterioration preventive inhibitor is mixed in the oil.

c. Countermeasures taken for the prevention of water condensing on the surface of insulations and metal parts of electric equipment.

When high temperature, high humidity-laden air enters the casing of enclosed switch cubicles, metal-clad switch gears, generators, motors, etc., it causes the condensation of water content on the inside surface of the casing if its temperature is below the dew point, giving several damage to the equipment as described in the Chapter I.

While the windings of the inside equipment are connected to the source, heat is generated by the electric loss so the inside is kept at the higher temperature than the breathed air and the condensation does not occur. But when the power source is cut, the inside temperature is often lowered down to the dew point. To prevent this, it is an usual practice to install a heating resistance inside and use it to warm the inside while the equipment is not operated. For instance, at the thermal power plant and substations in Okinawa, supplied by Japanese manufactures, heating resistances are installed in all equipment including the turbine generator (a 3 kW heater for 11,500 kW capacity), the unit substation cubicle, totally enclosed fan-cooled electric motors for auxiliaries, to be switched on whenever the equipment is in standstill. In some other cases such a measure was taken in an occasion that the cubicle was not sealed but the inner surface was covered with grains of cork adhered together with varnish to the thickness of about 5 mm, and ventilated at a proper air speed for the purpose of minimizing the differance between inside and outside temperatures.

Application of anticorrosive paint on the metal surface is desirable for preventing bad effects resulted from water condensation, and the melamine paint has been considered best for the purpose. The phosphate treatment on the steel surface preceding anticorrosive paint coating adds much to its effectiveness as the treatment shields the steel surface from air and water and better the sticking of the paint.

As regards the plating for anticorrosive purpose, the thickest possible double plating is recommended. By way of example, it may be quoted that a instrument manufacturer applied on the meter surface the copper plating to above 6 μ thick and replated with nickel adding thickness of over 8 μ.

Summary

The electric machines and apparatus used in tropical and sub-tropical regions are naturally operated under an undesirable conditions of high temperature and high humidity. Hence their insulations must be treated for the prevention of moisture first of all. Otherwise, there occurs inevitably the absorption of moisture by the insulating materials and it leads to the gathering of moulds on their surface, resulting in a severe damage to those. Again, if the sudden change of temperature comes over, the moisture condenses in water drops on the metal surface of the equipment, which incurs the corrosion of the equipment and deterioration of the insulation oil.

The climates in Japan are characterized by long lasting visitation of high humidity in summer season, coupled with high temperature. This explains the rapid rate of moisture absorption occuring in Japan which is fairly comparable to that in tropical regions.

Thus, manufacturers of electric machines and apparatus in Japan have had long way to overcome such unfavourable conditions for their products. In the course of their research works for establishing effective countermeasures, the tropical service model test-code was stipulated in 1942, the summary of which are introduced herein.

Introduced also in the article are a comparative study on the moisture prevention characteristics of various kinds of varnishes conducted for obtaining a batter dry insulation for generators, electric motors, oil-less transformers, etc., together with the results of the experiment for several types of mould repellent paintings.

The article relates further of some methods of nitrogen gas sealing for oil-immersed electric apparatus such as oil transformers, the method of preventing water condensation on the inner surface of switchboxes and the like, and, in the end, the researches carried out on the anti-corrosion paintings.

Résumé

Les machines et les instruments électriques employés dans les régions tropicales et subtropicales, étant exposés en général à la haute température et à la grande humidité, l'isolant qui n'est pas protégé contre l'humidité par le traitement convenable, diminue sa qualité isolatrice; la surface de l'isolant, qui a absorbé l'humidité, est moisie, et sa qualité s'abaisse; la surface des métaux de l'équipement est rouillée par la condensation de la vapeur, et l'huile isolante diminue sa qualité. Au Japon, la durée de la haute température et de la grande humidité étant longue en été, la vitesse de l'absorption de l'humidité est comparable à celle des régions tropicales, et on étudiait depuis longtemps la méthode de la protection contre ces conditions défavorables. En 1942, on a établi le

reglement des essais executes sous les conditions [illegible] [illegible] sommaire du reglement dans la these. On exposera ensuite les etudes comparatives des caracteristiques preventives contre l'humidite des vernis de toute sorte, ces etudes etant necessaires pour obtenir l'isolement sec du generateur electrique, du moteur electrique, du transformateur sans huile, etc., et les resultats des experiences concernant les peintures repercussives de moisi. D'ailleurs, on exposera la methode d'enfermer le nitrogene dans les apareils qui contiennent de l'huile, tels que le transformateur, pour les proteger contre l'humidite, le moyen d'empêcher la condensation de la vapeur sur la surface interieure de la boite d'interrupteur et des autres, et les etudes sur les peintures contre la rouillure.

Resumo

As máquinas e aparelhos elétricos que funcionam em regiões tropicais e sub-tropicais operam, naturalmente, sob condições precárias de temperatura e humidade. Por isso deve-se cuidar dos seus isolamentos contra a humidade antes de tudo. Do contrário se verifica, inevitavelmente, a absorção da humidade pelas matérias isolantes, donde resulta a acumulação de môfo em sua superfície, danificando-as grandemente. E ainda, se uma súbita mudança de temperatura sobrevém, a humidade do ar se condensa em gôtas dágua na superfície metálica da aparelhagem, acarretando-lhe a ferrugem e a deterioração do óleo isolante.

No Japão, as variações climáticas são caracterizadas pela presença constante de alta humidade no verão, conjuntamente com elevada temperatura. Isto explica a rápida marcha da absorção da humidade que ocorre no Japão, a qual se pode, perfeitamente, comparar com a das regiões tropicais.

Assim sendo, os fabricantes de máquinas e aparelhos eletricos no Japão, desde muito conseguiram, com seus produtos, superar tais condições desfavoráveis. No decorrer de seus trabalhos de pesquisas para estabelecer efetivas contra-medidas, estabeleceu-se, em 1942, o regulamento modêlo para os ensaios sob condições tropicais, sendo o respectivo resumo incluido na presente monografia.

Na monografia se inclui, igualmente, um estudo comparativo das caracteristicas preventivas contra a humidade das várias espécies de vernizes, com o fim de obter-se o isolamento sêco para os geradores e motores eletricos, transformadores sem óleo etc., juntamente com os resultados das experiências com os vários tipos de pintura contra o môfo. Alem disso a monografia expõe alguns métodos de vedação de aparelhos eletricos imersos em óleo, tais como transformadores a óleo, o método para evitar humidade na superficie interna das caixas de interruptores e outras, e finalmente as pesquisas feitas em relação com as pinturas contra a ferrugem.

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REUNIÃO PARCIAL
SECTIONAL MEETING
Rio de Janeiro — 1954

TANAKA (M.)
Japão

THE IMPROVEMENT OF BAGASSE-FIRED BOILERS

By MASUZO TANAKA
[illegible]
JAPANESE NATIONAL COMMITTEE

I INTRODUCTION

It is a general practice in cane sugar mills that their boilers serving as a power and thermal source make use of bagasse produced from sugar canes ground and extracted of juice as a convenient fuel.

In early days of sugar manufacturing when sugar canes were rich of fibre content for its scanty sucrose content, and the refining process could not go further than the production of raw sugars, sugar mills almost without exception were replete of and harassed by the excess leavings of the bagasses. Following the steady and repeated improvement, the sugar canes have come to show a noticeable increase in sugar content in inverse ratio to the fibrous structure, while the extraction efficiency in sugar mills has reached so high to 98.22% that the output of raw sugar has marked a remarkable increase. And the improvement in technique in getting the higher purity of sugar had followed that the sugar mills were running short of the bagasses for fuel, and were compelled to have recourse to the auxiliary fuel supply such as coal and oil, and, as a result, the price of auxiliary fuel bought from outside has become a factor to accelerate the rising of the sugar cost. Under such situation, sugar companies, fully recognizing the need for the improvement of the bagasse-fired boiler, had started in the research in competition for developing a more efficient type of the boiler.

The writer set about the study of the bagasse-fired boiler in 1928, just a quarter century back, when the sugar industry was already complaining of the shortage of the bagasse and supplemented with coal for more than 15% of its total heat requirement, and in the Formosa where he engaged in the study there were almost 50 sugar mills which were

producing upwards of 1,500,000 tons of annual output at the rate of [illegible]

Along this course of sugar history the writer has accumulated the results of his research works on the boilers year after year, and the construction of such high efficient type of bagasse boiler as detailed in the following pages has been originated.

With such remarkable achievements in many places, this bagasse-fired boiler is in extensive use in almost all sugar mills in the Formosa as a standard type for these sort of boiler.

2. COMPOSITION AND HEATING VALUE OF BAGASSE

Bagasse consists of cane fibres with remnant sugar and considerably high content of moisture. In line with the development of the sugar cane mill, the moisture and remnant sugar contents have come to show a remarkable trend to decrease that the former occupies 36 – 38% and the latter only 2% of the whole value, and it follows that in most bagasses the fibre content exceeds 60%. In case of sugar canes, the fibre content ranges from about 11 to 13%, giving and average of 12%. Although there are many reports publishing the compositions of the fibre in ultimate analysis which differ from each other, values given out in those information can be summarized as follows:

		(Average)
Carbon	12.16 – 55.19%	47.25%
Hydrogen	5.00 – 6.51%	5.91%
Ash	1.10 – 2.11%	1.51%
Sulphur	41.22 – 51.11%	45.27%

Although it is difficult to measure precisely the heat value of bagasse, it is known practically that dry bagasses develope the average heat of 4,800 kcal/kg., ranging from 4,600 to 5,000 kcal/kg. Fibre and remnant sugar contents in bagasse were daily analysed and recorded at every factory and based on those data the higher heating value can be calculated for convenience by means of the following equation:

$$H = 4750\,F + 3955\,S \;\ldots\ldots\; \text{kcal/kg.}$$

where F and S represent the contents of fibre and sucrose in 1 kg. of bagasse respectively.

In the general expression for the higher heating value the sugar content is subdivided in sucrose and glucose, but the latter contents are so small that may be neglected in practical use. Moreover, as the moisture content of bagasse shows almost constant value, the procedure is conveniently omitted and the boiler efficiency is calculated making use of the higher heating value as standard.

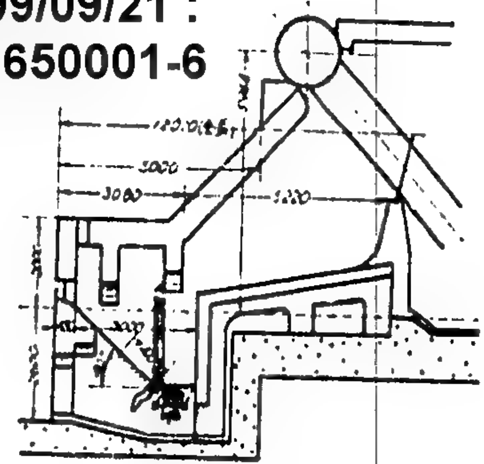

Fig. 1

3. INVESTIGATION OF BAGASSE FURNACES

In 1927, a bagasse-fired Takuma (15° inclined) water tube boiler having 214 m² heating surface was trially designed and manufactured and in the following year, four boilers improved from the prototype were completed, the schematic diagram of which is as given in Fig. 1.

At the same time, two boilers of entirely different construction as illustrated in Fig. 2 were installed, and these two types were studied in comparison. Specifications of the furnace of the two are as given in Table 1-A and B respectively.

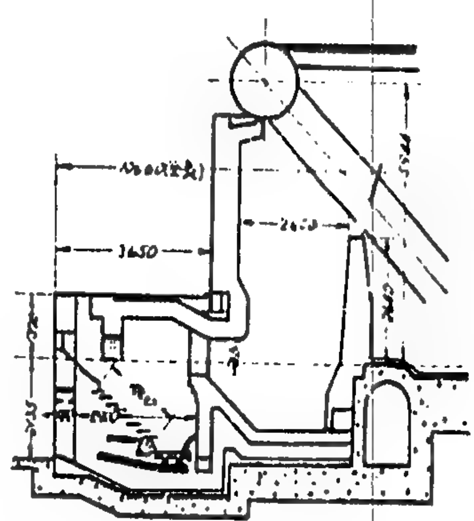

Fig. 2

TABLE 1

	Kind of boiler	Boiler surface (m²) a	Normal evaporation (kg/h)	Grate area (m²) Stepped surface	Flat surface	Rear tuyere	Total b	Furnace section & width mm	Slop of grate	Furnace volume (m³) 1st	2nd	a/b	Rate of combustion (kg/m² h)
A	Takuma	301.0	9,100	2.70	1.53	0.97	5.20	2 × 1011 2082	40°	14.4	41.4	58.1	313
B	"	219.5	7,620	4.23	1.61	1.01	6.85	2 × 1168 2336	32°	11.7	51.8	32.0	318

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What is worth special mention in the boiler A is that: the length [illegible] were reduced to increase the combustion rate: In the boiler B, in the meantime, the length and the width of fire grate were enlarged to decrease the combustion rate; conventional drop nosed arch was employed; and both side walls of the second chamber were built in air cooling type passing through the primary air, and then the primary air was led under the fire grate through the furnace bottom thus accelerating a complete combustion. In both boilers a flat grate was installed about 250 mm under the lower end of the step fire grate and combined with a dumping grate which makes the ash removal during operation easy. Clinkers were taken away from between the lower end of the step fire grate and the flat fire grate. For the better draft, at the rear end of the flat fire grate were located the tuyeres consisting of arched bars stood against the fire bridge. Moreover, the partition wall was provided in the furnace for cleaning fire which was regarded to be necessary for the boiler operation in those days.

These two types of the boiler, both attaining the expected evaporation of 30 kg/m²/h for a unit heating surface, provided to be several steps superior to the conventional ones, yet each of them had its own demerits to be remedied. In the boiler A the draft was liable to become too strong in the course of thickening the fire bed, which is necessary for this boiler, and it gave rise to the blow hole which allowed the centering of draft causing a wide scattering of bagasse piles heaved around, thus it grew voluminously. Then the green bagasses coming astray under fire bed. In the repetition of such whirling of draft, the fire bed could scarcely keep its uniformity and resulted in unstable combustion. In case of the furnace B, by doing away with the passing of primary air through both side walls and increasing secondary air combustion was stabilized by the procedure with the value of CO_2 maintained at 15 - 16%, noticeably adding the capacity of the boiler. For all the above, however, the problem remained unsolved that green, hard clinkers were formed and accumulated on the bottom of the secondary furnace.

Thus, their left-overs were accumulated to about 1.3 m by the end of grinding season and asked for several days' work for perfect removal.

In the boiler A, there were no clinker troubles but much labour was needed to remove the ash piled over the extensive bottom area of the secondary furnace.

In a successive effort to improve the above two types, several remodellings were applied; i.e. in the furnace of the boilers of A system for the purpose of minimizing the ash pilling the first chamber was brought closer to the boiler part by lowering the fire bridge and the bottom of the second chamber was given a greater slope. Likewise in the furnace of the boilers of B system the drop nose arch was discarded for the flat arch to determine its influence on the production of clinker, and the bottom of the second chamber was filled flat and built in a steep grade, thus to force the clinker to slide into the first chamber.

The inclination of the bottom and the length of step grate were varied [illegible]st combustion chamber of the boiler B was built in complete flat grate type. On top of these considerations and researches, a series of study was conducted as to other types of boilers, which had been constructed in various places.

These reconstructed types were designed based on the type illustrated in Fig. 2, and characterized by particularly enlarged second combustion chamber. In these type of boilers by reducing the draft force as much as possible the scattering of ash was withheld greatly, the fact which side by side with the broadness of bottom space remarkably reduced the thickness of clinker layer, enabled an uninterrupted operation for a whole grinding season, and sometimes raised the boiler capacity and the combustion efficiency from the previous value, 20 kg/m² G.H.S. h, to 23 - 25 kg/m² B.H.S. h, averaging 3.25 kg/kg of bagasse.

However, it should be noted that these types offered a difficult job of removing the accumulated clinker at the end of one season. In addition, the furnace wall suffered from much damage due to higher temperature of operation, and, in case of the boilers of 25 kg/cm² steam pressure, water tubes on the lower side were bulged by overheating.

Hence it was imperative to limit the load by reducing the grate area or to install the water walls.

From the above researches, the following conclusions were derived as regards the combustion of bagasses:

(1) In spite of its much moisture content, bagasse makes an intrinsically good fuel due to the fitness of its size to combustion.

(2) The rate of combustion is so high that the excess air ratio of 20-30%, CO_2 16% or over can easily be kept.

(3) When the flat fire-grate is used, the fuel is burned in a conical pile, hence incomplete combustion is resulted by poor draft for the interior of it, and in addition, clinker is produced as ash is gradually piling up on the fuel cone, which makes necessary a periodical cleaning fire. And as with steep-graded shape of the cone, this grate causes a temporary abatement of fire when large amount of green bagasses is fed at one time due to the supply will cover the whole fuel pile surfaces. On top of that, with this type of grate as it is difficult to form a complete turbulence, the good combustion efficiency and the stable combustion of the boiler considerably set back except the cases where the load requirement is low or there is no sudden change of load. Moreover, as the second chamber needs to be built by providing the drop nose arch for the betterment of combustion efficiency, clinker troubles become all the more inevitable.

(4) In case of the equipment with the step fire grate, when bagasses are stuffed, the evaporation of water occurs at its upper zone followed by the distillation of the volatile matter and at the lower zone is produced CO gas, then the bagasse completes combustion

on the flat grate. This rational sequence of combustion along with [illegible] space of the burned bagasses became vacate owing to a minimum quantity of ash and the upper layer of the bagasse fuel easily fill the space by the gravity and moving lower, makes this type of equipment efficiently. By extending the top of the step fire grate with a simple slant assembling of bricks enough drying section can be easily reserved for the bagasses, and by this arrangement, the combustion rate is added noticeably with particularly strengthened burning even below the center part of the grate.

Hence, when a large amount of green bagasses is supplied at one time the combustion is not only disturbed, but also it takes fire immediately adding so much to the total force of fire enabling to comply instantly with the incr ase of load requirements. It should be noted here that, the angle of grate inclination presents a major problem, and in many a case the inclination is made in around 50° following the old practice. However, in this order of inclination, the bagasse tends to gather up at the bottom and are apt to impose weight to excess on the fire bed resulting in high density of fuel, and accordingly poor ventilation is brought about to cause imperfect combustion. Meanwhile, it has been experienced that if the incline is reduced to 35° it rather checks an easy sliding of the bagasse supply.

After the repeated experiment in this connection, it has been proved that a best result is obtainable by the inclines varying from

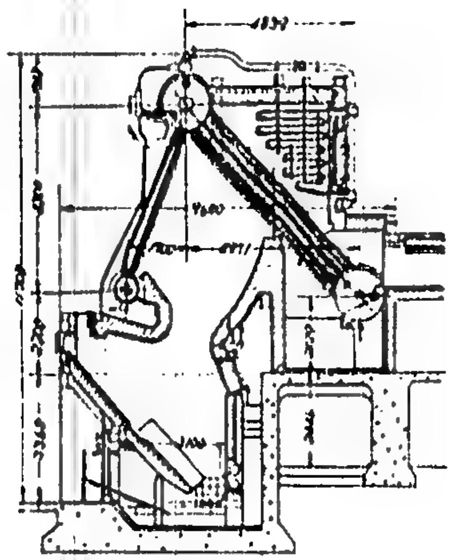

Fig. 3

38° to 42° according to moisture content and sizing of the bagasse [illegible] requirements. In this case, moreover, the turbulence of the combustion gas is formed in a most efficient and appropriate whirling.

4. THE LATEST DEVELOPMENT OF BAGASSE FURNACE

In studying the above, it was concluded that the idea of two-combustion chamber system might not be sticked to in designing the bagasse furnace. With the above experiences the writer has been convinced that the removal of the moisture was surely attainable by extending the inclined plane of the step fire grate, so the writer launched into the designing of the epock-making one-combustion chamber furnace for bagasse firing, as it has been used burning coal, oil and gas.

This outline shows in Fig. 3 and fabricated two boilers as specified on Table 2 respectively.

TABLE 2

Kind of boiler	Takuma water tube boiler	
Type	FL — 500	FL — 700
Boiler surfaces — (m²)	344	490
Furnace width — (mm)	3,040	4,360
Furnace depth — (mm)	3,900	3,900
Furnace volume — (m³)	67	85.2
Ditto under the throat — (m³)	31	36
Step grate length — (mm)	4,600	4,600
Normal evaporation — (kg/hr)	11,000	16,000
Ditto — (kg/m²BHS hr)	32	32.7
Max evaporation — (kg/hr)	13,200	19,200
Ditto — (kg/m²BHS-hr)	38.5	39.2

The special feature of this latest design lie in;

(1) The combustion chamber is single and installed right beneath the steam drum. The furnace is lengthened, and an ignition arch is built at the center of front wall to accelerate the ignition as well as the vaporization of water content. The center part of fire bridge is projected to form a throat communicated to the ignition arch

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and thereby such ample combustion chamber volume is provided that combustion can be completed inside. High temperature zone of grate area and combustion chamber is exposed to the heating surface of the boiler in order to prevent an excessive rising of temperature. Upright flaming is made best use of preventing sidewise spreading of flame and the draft loss is precluded. Moreover, the projected part of the fire bridge and the throat are given an appropriate size according to the amount of moisture in bagasse.

When the bagasse containing 38-40% of moisture is burned, with the contracted throughout of 600 mm, the furnace temperature becomes well over 1,400° C. and the clinker is observable to drip down in trickles from the fire bridge. In this case, if the throat is widened to 1,200 mm, the most fitted temperature, or slightly over 1,200° C. is obtained.

(2) As the grate slope is extended to the longest possible extent, drying, distillation, ignition and combustion of bagasse can be proceeded in good order.

(3) Since the draft is extremely reduced by allowing the entering of primary air in only an auxiliary scale no blow hole is caused in fire layer and accordingly even fire layer and stable combustion are realized.

(4) Effective turbulence of combustion gas is developed by introducing in the secondary air from three passages in the direction of, i.e.:
   a. From right behind the bagasse feeder, parallel to the grate slope,
   b. From under the fire bridge, in upward of 15°, and
   c. From lower sloped portion of the fire bridge, in horizontal.

   Moisture, generated in the upper part, goes down and is utilized effectively as a catalysis for CO gas combustion. The combustion is accelerated with a supply of air blown in 15° upward direction from lower part and completes its full process with a horizontal air flow coming from under sloped portion of the fire bridge. At the same time, a part of high temperature gas ascends along the sloped grate in a whirl causing a whirlwind of whole furnace gas.

(5) The slope of grate area is conveniently able to be adjusted over the range of 37°-15°, hence the fire strengthened and the capacity is enlarged enabling a quick response to a sudden increase of load, as aforementioned. Bagasses, turned into ash after a gradual combustion, fall down evenly and are brought to horizontal grate situated at the lower end. Accordingly, ash removal is very simple and troublesome cleaning fire is made almost unnecessary.

(6) Combustion efficiency is so improved and stabilized that the generation of CO_2 gas can be maintained at the rate of 15-16% at normal condition and at even 16-17% by skilled operators.

(7) Age-old clinker trouble has been solved forever with a disappear-

ance of both producing and piling spot of clinker in the furnace, [illegible] free from troubles for all grinding season has been made possible.

(8) As excessive rising of the furnace temperature is prevented beforehand the durability of the furnace as well as the fire grate is increased and the maintenance is cut down almost to nothing.

(9) Since the clinker trouble is entirely remedied, thermal efficiency is improved still more by utilization of air preheater and the boiler capacity is added by 20%.

(10) The Takuma boilers, at its incipient stage of development, showed the values of 32 (average normal) to 38 (average max.) and by the latest improved type herein described the values have been soared at last to 37.8 (average normal) and 40 (average max.) kg/m² BHS/h. At the same time, the efficiency has shown such a gain as large as 70% when calculated on the basis of higher heating value

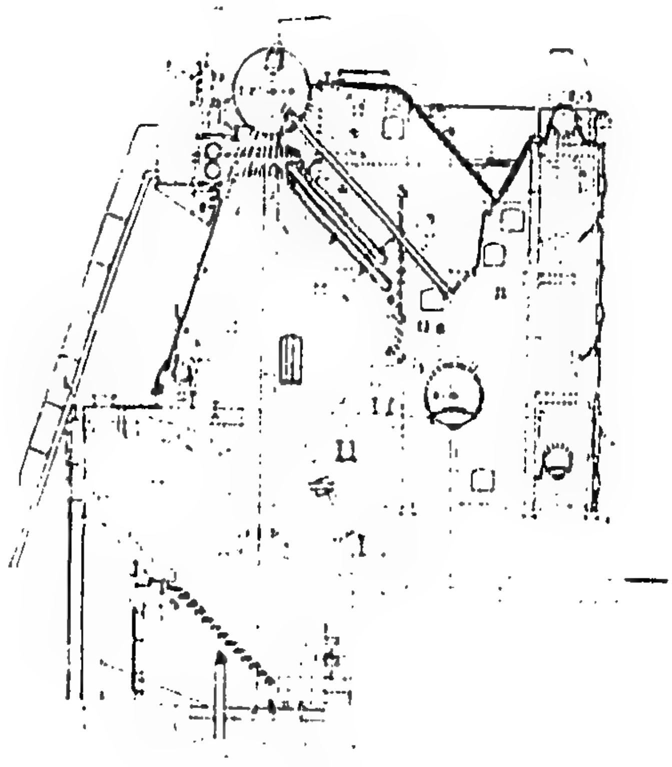

Fig. 4

TABLE 3

	Type & boiler surface m²		Takuma FL-720 491		Takuma FL-500 385		Takuma FL-5[illegible] 3[illegible]	
Fuel	Bagasse consumption	kg/h	4,630	5,480	3,350	3,570	3,660	[illegible]
	Combustion rate below the throat	kg/m²/h	128.5	152.5	110	117.1	121	[illegible]
	Surface moisture	%	39.5	39.1	36.2	36.2	40	[illegible]
	Higher heating value as fired	kcal/kg	2,818	2,825	2,980	2,980	2,858	[illegible]
Steam	Evaporation	kg/h	16,100	18,500	12,500	12,700	12,100	12,750
	Pressure	kg/cm²	8.15	8.68	6.58	6.86	10.15	10.2
	Feed water temp.	°C	95.6	95	99	99	95.8	96.2
	Equivalent evaporation	kg/h	17,550	19,450	13,000	13,250	12,900	13,600
	" of boiler	kg/m²/h	35.5	39.75	37.8	38.35	37.6	39.5
	" of bagasse	kg/kg	3.75	3.55	3.93	3.72	3.50	3.53
Gas	Furnace temp. max	°C	1,176	1,240	-	1,270		--
	Boiler inlet temp	°C	1,054	1,088	-	985	-	
	Boiler exit temp	°C	260	262	221	236	211	254
	CO_2	%	14.5	15.2	15.5	16.88	15.16	15.16
Efficiency	Higher heating value standard of bagasse as fired	%	71.85	67.72	71.06	67.1	68.2	67.3

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TABLE 4

Name of sugar mills	Cane ground		Bagasse-fired boiler				Cane ground per 100 m² of boiler surface		Boiler surface required for grinding per ton of cane
	t/day	t/h	No. of sets	Type	Heating surface (m²)	Total heating surface (m²)	t/day	t/h	m²/t/h
Nantou	1,440	60	5	B & W	444	2220	65.0	2.7	37
Tsungyeh	1,440	60	5	Takuma	240	1200	120.0	5.0	20

N.B. Economizer, air preheater and auxiliary fuel are not provided in either type of boilers.

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standard for consumed bagasse, and in one instance a creditable [illegible] equivalent evaporation from and at 100° C per kg. of bagasse as fired has been reported.

Table 3 shows a summary of records of experiments carried out for the latest design;

Table 4 shows the performance data of Tungyeh and Nantow works, comparing with improved boiler and conventional boiler, where the both works have no difference in the age of their manufacturing facilities.

5. CONCLUSION

With the completion of the Takuma boilers in the latest, improved design, a marked decrease has been made feasible in the consumption of auxiliary fuel, and many a factors which has adopted this new boilers is being turned into a so-called no-coal factory in increasing number.

In the history of development of this boiler, CT type sectional boiler of two combustion chamber system have been installed, and several compartments are provided under the fire grate, each compartment being equipped with a damper for the separate adjustment; in addition, both water walls and air-cooled walls are installed for the purpose of preheating of combustion air supply. These plant, comparing with improved single combustion chamber system, should have proved to be a success considering the complicateness of its construction. Still more, it accompanied considerable difficulty in operation and tremendous ash piling on the bottom reaching two meters of thickness only in a period of 10 days, and could not go on continuous operation moreover. Disappointed with the results this type was thoroughly displaced in the next year with the improved Takuma type.

After the management of all cane sugar mills in the Formosa had been taken over by the Chinese Sugar Co., a further improvement was incorporated in the above type and the "Tsurekichi" water tube boilers as shown in Fig. 4 are now in service as a remodelled type. The construction of this furnace is very similar to that of Fig. 3; heating surface of boiler is 604 m², steam super heater 220 m², economizer 353 m², evaporation 20 t/h to 25 t/h max.

As can be understood from these values, this boiler has ample capacity to depend upon, and is featured by simple construction of furnace which asks for no special stoker. The low cost of installation and maintenance, the ease of handling, the possibility of continuous operation, and the total efficiency of 71.1%, derivable by the use of the bagasse of 60% fibre content, 2% sucrose, 38% moisture and 2930 kcal/kg. higher heating value, which is equivalent to the evaporation of 4 kg. for every 1 kg. of the bagasse, are expressing themselves as a sure proof of completeness of the design which denies the necessity or the possibility of further

improvement of the Tsunekichi water tube boiler for some time in any

SUMMARY

Generally, for the power and heating sources required in the cane sugar plant, bagasse obtained from compressing the sugar cane is utilized. Many of the sugar plants in Formosa encountered difficulties in disposing of this surplus bagasse during the days when they were manufacturing raw sugar only. However, with the improvement of sugar cane and the remarkable advance in extraction rate, the production of bagasse dropped greatly, while on the other hand, the sugar production increased tremendously, causing the shortage of bagasse as fuel. The writer commenced study of the bagasse burning boiler in Formosa in 1928, during the time of this bagasse shortage. Since then, we have concentrated our efforts on study and research to perfect a bagasse burning boiler with high evaporation capacity by causing the bagasse to be effectively burnt. In this paper, its development is described in detail, especially the course leading to the standard bagasse burning furnace design in Formosa. The latest performance data are also described.

The points which happen to be the problems particularly in this study are:

(1) To eliminate the troubles in burning caused by water content of the bagasse
(2) To prevent the flying of bagasse, uneven fire bed and unstable combustion, as well as difficulties caused by sudden changes of load.
(3) To prevent hindrances to continuous operation due to the accumulation of ash and formation of hard clinker.
(4) To increase the combustion efficiency and evaporation rate and to secure the easy maintenance of furnace, preventing the furnace from overheating.

After many years of research, the writer has reached the following conclusions:

(1) Single combustion chamber similar to that used for ordinary fuel is recommendable more than the prevailing double chamber.
(2) The secondary air should be used as the principal, with the primary air as supplementary.
(3) Long step grate with gradual inclination should be used in combination with the horizontal grate

With these major improvements, we succeeded in obtaining far better results than the coal burning travelling grate stoker. The evaporating

capacity of the boiler has reached an average of 37.8 kg/m²·h, while [illegible] higher calorific value has been obtained.

Résumé

En général, dans les usines sucrières, on utilise la bagasse, résidu obtenu en pressant la canne à sucre, comme source d'énergie et de chaleur. Pendant la période où l'on a fabriqué le sucre brut, un grand nombre d'usines à Formose ont éprouvé de la difficulté tour utiliser la bagasse en trop; mais avec l'amélioration de la canne à sucre et le progrès de l'industrie sucrière, la production de la bagasse a rapidement diminué et, d'un autre côté, la production sucrière a considérablement augmenté, la consommation de vapeur augmentant encore davantage. C'est pourquoi la bagasse, en tant que combustible, ne pouvait satisfaire les besoins.

C'est à cette époque, en 1928, que je me suis mis à étudier la chaudière à la bagasse. Depuis, je me suis efforcé d'obtenir la chaudière à la bagasse à grand rendement de vaporisation, qui brûle efficacement la bagasse.

Dans cette these, j'exposerai l'histoire de cette étude, sa marche suivie pour arriver a obtenir la chaudière-type à Formose et le récent résultat atteint.

Les points mis en évidence en particulier dans cette étude sont les suivants:

(1) éliminer les troubles de combustion causés par l'humidité contenue dans la bagasse.

(2) empêcher l'échappement de bagasse, le courant de flamme non uniforme et l'instabilité de combustion, pour répondre immédiatement au brusque changement de la charge;

(3) éviter l'inconvénient de l'operation continuelle dû à l'accumulation de la scorie dure.

(4) faciliter la conservation de la chaudière, en augmentant le rendement de combustion et celui de vaporisation de la chaudière, mais en empêchant sont surchauffement.

Après de longues annees de recherches, j'ai conclu que: (1) le système d'une chambre de combustion employé dans les chaudières ordinaires est plus rationnel que celui de deux chambres employé jusqu'à présent; (2) l'air secondaire doit être principal et l'air primaire supplémentaire; (3) les grilles longues de l'inclinaison graduelle doivent être employées en combustion avec des grilles horizontales .

J'ai pu ainsi realiser l'idéal du fourneau à la bagasse et réussir à avoir le modèle-type.

Avec ce modele perfectionne, nous avons obtenu un meilleur résultat qu'avec des grilles mécaniques employées dans la chaudière à charbon. La capacité de vaporisation atteint en moyenne 37.8 kg/m²/h. et le rendement plus de 70%, dans le cas typique du haut échauffement.

RESUMO

Geralmente, como fontes de energia e calor nas usinas de cana de açúcar, utiliza-se bagaço obtido da moagem da cana de açúcar. Várias usinas de açúcar em Formosa encontraram dificuldades em dispor do excesso de bagaço no tempo em que fabricavam apenas açúcar bruto. Todavia, com o melhoramento da cana de açúcar e com o progresso da indústria, a produção do bagaço diminuiu consideravelmente, enquanto, por outro lado, a produção açucareira aumentou consideràvelmente, ocasionando a falta de bagaço para combustível. Esta é a razão pela qual o bagaço como combustível não correspondia mais às necessidades.

O autor da monografia começa o estudo da caldeira a bagaço em Formosa em 1928, ou seja na época da falta dêste combustível. Desde então o autor concentrou seus esforços no estudo e pesquisa no aperfeiçoamento para o projeto de uma caldeira utilizando o bagaço com alta capacidade de evaporação e queimando-o eficazmente. Nessa monografia seu aproveitamento é descrito em minúcia, especialmente quanto à marcha seguida para se chegar a obter a "caldeira-tipo", em Formosa, e os últimos resultados obtidos.

Os pontos particularmente evidenciados nesse estudo são:

(1) Eliminar as perturbações de combustão causadas pela humidade contínua no bagaço;
(2) Impedir o desperdício do bagaço, a corrente de chama não uniforme e a instabilidade de combustão, tão bem como as dificuldades causadas pelas súbitas alterações de carga;
(3) Evitar transtornos na operação contínua devidos à acumulação;
(4) Aumentar a eficiência da combustão e o regime de evaporação da caldeira e assegurar-lhe a fácil conservação, impedindo-lhe o superaquecimento.

Depois de longos anos de pesquisas, o autor concluiu que:

(1) O sistema de câmara de combustão (de forno ou fornalha) empregado nas caldeiras comuns é mais racional que o que prevalece na de câmara dupla empregado até o presente;
(2) O ar secundário deve ser usado como principal, e o ar primário por o suplementar;
(3) Longa grelha escalonada de inclinação gradual deve ser usada em combustão com grelhas horizontais.

Pôde assim o autor realizar o ideal de forno a bagaço e chegar a realizar o modêlo-tipo.

Com êsse modêlo aperfeiçoado, o autor obteve melhor resultado do que com as grelhas mecânicas empregadas nas caldeiras a carvão. A capacidade de vaporização atinge, em média, a 37.8 kg/m², e o rendimento a mais de 70%, nos casos típicos de alto aquecimento.

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Título 1
Assunto 1.1

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Rio de Janeiro - 1954

GADKARY (S.A).
India

COORDINATED DEVELOPMENT OF HYDRO AND THERMAL POWER RESOURCES IN INDIA

By SHRI S. A. GADKARY
B.E., C.P.E. (Tech), A.M.I.E.E. (London), M.I.E. (India)
Member of Central Water & Power Commission
Ministry of Irrigation and Power Government of India

INDIAN NATIONAL COMMITTEE

1. INTRODUCTION

Co-ordinated operation of Hydro and Thermal Plants implies utilisation of both resources to maximum advantage, and development based on this principle aims at securing maximum overall benefits – reflected in increased firm load carrying ability, low operating costs and a variety of less tangible benefits – from a given investment on Power Generation. Although there have been some isolated instances of co-ordinated development of hydro and thermal resources in this country, it can be said that, up to the end of the last decade, hydro and thermal plants sprung up generally independent of each other. This was due to the fact that there are few regions in the country where there is a relative abundance of both resources, capable of easy utilisation, and developments hitherto have not been very ambitious. In 1951, thermal plants represented 68.66% of the installed capacity and supplied 51.19% of the total energy generated, while the corresponding figures for hydro are 31.34% and 18.81%.

Towards the end of the last decade, the Damodar Valley Corporation, set up primarily to afford flood protection to the Damodar Valley in West Bengal and aid in its general development, planned the construction of a number of low head flood control dams, which would enable the generation of a certain amount of hydro power in a region where the country's resources of coal are concentrated. Development of power in this region has rightly been planned on the basis of co-ordinated operation of both hydro and thermal resources.

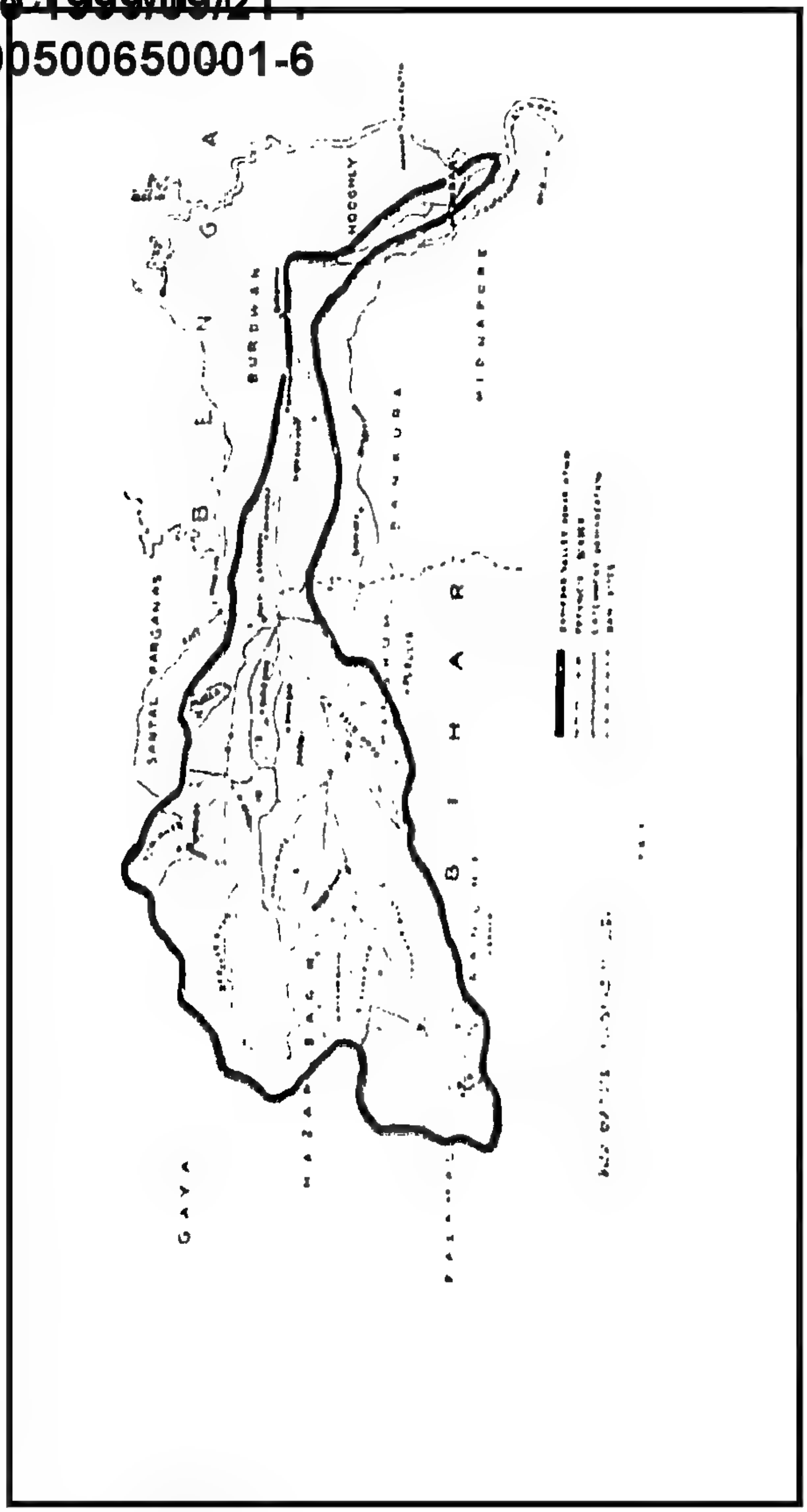
At about the same time, the Tata Power System in Bombay, an [illegible] was hit by a spell of consecutive years of low rainfall at a time when the system was fully loaded and no expansion shemes were in progress. Immediate further expansion of generating facilities are being carried out on the thermal side, even though fuel has to be transported across hundreds of miles to the area.

The extent of co-ordination that should be effected between these two resources is as much a matter of economics as it is of sound engineering. Tata Power System in Bombay represents a case where hydro power, generated at high head stations, is as cheap as it can possibly be in this country. On the other hand, thermal power at Damodar Valley Corporation Bokaro Station near a coal mine can be generated at the lowest cost practicable for new thermal stations, hydro power in this area considered independently being expensive relative to thermal power. It is the purpose of this paper to explain with the help of these two examples the problems that are involved and indicate the importance of the subject to India's further power development programme

II. (a) DAMODAR VALLEY CORPORATION

The Damodar river rises in the hills of Bihar in the North Eastern part of the country, flows eastwards, enters the State of West Bengal soon after its confluence with the Barakar, its chief tributory, and ultimately discharges into the Hooghly, below Calcutta. The upper reaches of the river in the State of Bihar are hilly and generally suitable for the construction of low dams to absorb the floods. In the lower reaches, the river cuts through the plains of West Bengal, which it frequently subjects to overflow during floods, causing extensive damage. Damodar Valley Corporation's scheme of control of the Damodar and general development of the valley, involves the construction of a number of dams in the upper reaches of the river, intended primarily for flood control, the controlled releases from the reservoirs being utilised both for generation of hydro power and for irrigation in the plains which lie beyond.

Of the various plans, the one finally adopted assigns the main task of controlling the floods of the Damodar and the Barakar rivers, to the Panchet Hill and the Maithon Reservoirs, built on the respective rivers slightly above their confluence. Fig. 1 shows the map of the Damodar Valley. Lying close to the area intended to be protected and commanding a fair part of the catchment, they appeared best suited for the function. The Tilaiya and the Konar Dams higher up the river, and those that may be constructed later on, will be operated in the interests of irrigation and power, with flood control as an incidental benefit. Tilaiya controls only 5% of the entire catchment, and its contribution to power, about 2600 kW firm, is therefore small. Storages provided at Konar, Panchet Hill and Maithon permit generation of about 17,000 kW, 6,000 kW and 8,000 kW respectively on a continuous basis, throughout



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the year. However, during the monsoon period which may extend from three to four months, a considerable amount of power, 40,000 kW and more, would be available from each station. Plans have therefore been made to instal sufficient plant capacity at the three dams to generate as much hydro energy as possible, which amounts to a total of 526 m.kW/hrs. in a year, and "firm-up" this fluctuating output by co-ordinated operation with Bokaro Thermal Plant, a station with an ultimate capacity of 200 000 kW, to be operated initially with three units of 50,000 kW each. This plant is designed to use the high-ash-content coal available in large quantities and at low costs near the power station. It has been located on the banks of the Barakar, enabling the controlled releases from Konar Hydro, of 400 cusecs, to be used for cooling purposes.

If sufficient storage had been available at Konar, Panchet-Hill and Maithon, the hydro energy available could have been theoretically used to meet a system peak load of about 200,000 kW at the anticipated load factor of 60%. It is, however, uneconomical to provide such a large storage to achieve this regulation. As part of the D.V.C's multi-purpose programme, however, the total available hydro power on continuous basis would only be about 31,000 kW.

It would be seen from what has been stated in the preceding paragraph that, operated independently, the total load carrying capacity of all the D.V.C. stations would be 151,000 kW at 60% load factor, as shown below:

Name of Station	*Installed Capacity*	*Firm capacity at 60% load factor*
1. Bokaro	150,000 kW	100,000 kW
2. Konar	10,000 kW	28,000 kW
3. Maithon	60,000 kW	13,000 kW
4. Panchet Hill	40,000 kW	10,000 kW
Total		151,000 kW

As will now be explained, the total load carrying capacity of all the above four stations when operating in an integrated system would be 220,000 kW. This means a net increase of 69,000 kW in the load carrying ability of the co-ordinated system, and is achieved with only a slight incremental cost on additional hydro generating plant.

Co-ordinated operation of the D.V.C. is expected to be as follows: —

During the monsoon period, Konar, Panchet-Hill and Maithon would [illegible] the load curve (the maximum demand on all the three being about 120,000 kW), supplying all the energy that can be absorbed to the system base. The peaks during this period -- which will not exceed 100 MW, will be carried by two 50 MW thermal sets at Bokaro. The third unit will be held as reserve for the entire system. During the dry period — extending over 8 to 9 months — the thermal station would run at the base of the load curve, at a capacity of about 100,000 kW and hydro would meet the peaks to the required extent. The plant load factors on the three hydro stations during the dry period will be as follows:

1. Konar 12.5%
2. Maithon 20.0%
3. Panchet Hill 15.0%

It will thus be seen that with a total installation of 290,000 kW (150,000 kW Thermal and 140,000 kW Hydro), it is expected that a peak load of about 220,000 kW can be carried.

It would be further observed that in this case the load carrying ability of the combined steam-hydro system has been brought to the level which would have been attained if all the hydro energy were "firm" by itself without providing huge investments on storage. The operating costs are reduced to an extent, and the annual utilisation of 526 m.KW/hrs. of hydro energy on a firm basis enables partial economic justification of the main flood control dams. The cost of power at Bokaro's thermal plant is about 1.42 anna* per unit. The cost of hydro generation depends both on the incremental cost of installation of hydro plants at the dams, and the proportion of the cost of the dam that is allocated to power. While there are several methods of estimating the proportion of the cost that each benefit should bear, it is essentially an internal adjustment, and it is the overall picture that counts. The basis of allocation now proposed is that on the flood control dams, the costs should be borne in the ratio 1 : 1 : 1 on irrigation, power and flood control. The cost of hydro energy, worked out on this basis of allocation, brings down the cost of integrated D.V.C. power to 0.11 anna per unit.

Later stages of the Damodar Valley Corporation's programme involve the construction of more flood control dams, and additional generation of hydel power "firmed up" by additional thermal installations.

(b) TATA POWER SYSTEM OF BOMBAY

The Tata Power System, the largest energy producer in South East Asia, commenced operation as early as 1915. Backed by three high head

* 16 annas = 1 Rupee = 0.21 Dollars (U.S.)

Hydro stations, its growth has enabled industrial and other development for which there are no [illegible] solely in other resources of power. Main features of the three schemes are indicated in the following table:

	Catchment area (Sq. miles)	Av. annual run-off (m c ft.)	Storage provided (m c ft.)	Installed capacity (kW)	Average gross head (ft.)
Bhira	95.6	38,000	18,161	132,000	1713
Bhivpuri	48.0	9,800	12,852	69,000	1631
Khopoli	21.9	7,700	9,541	70,000	1725

The three hydro stations work in an interconnected system with the Chola Thermal Station of Bombay. The firm capacity of this thermal station at the moment is approximately 42,000 kW. Additional plant is now being added in this station and when the extensions in hand are completed, the firm capacity will increase to about 100,000 kW.

Figure 2 gives the load curve on the interconnected system on 27th August, 1952, and figure 3 shows as to how this load was being met by different stations. As will be observed, the total maximum demand was about 258,000 kW. In the case of Bhira Station, the average annual run-off is 38,000 m cft. As the storage is very much less than the annual run-off, it is obvious that this station should be run at the base of the load so as to permit maximum utilisation of hydro energy. In the case of Bhivpuri and Khopoli, storages provided are approximately twice the run-off left over after utilization in monsoon months. These reservoirs are thus capable of carrying over water from year to year enabling the two stations to be operated with great flexibility, and are therefore used for taking the peaks of the system. The Chola power station is run on the base of the load. From 12 midnight to 7 a.m., the system loads are comparatively small and are met by the Chola thermal station and the Bhira hydro station. From 7 a.m., onwards, Bhira and Chola run at the base of the load, and Bhivpuri and Khopoli take the peaks. The normal operation throughout the year is on the lines indicated above. The energy supplied to the system by different power stations on 27 August, 1952, was as under:

		Percentage of total
Khopoli	630,000	14.3
Bhivpuri	752,000	16.8
Bhira	2616,600	58.6
Chola	458,200	10.3
Total	4463,100	100.0

Daily load factor — 72%

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LOAD CURVE DAY HIGHEST TOTAL UNITS GENERATED (COMBINED SYSTEM) — AUGUST 27,

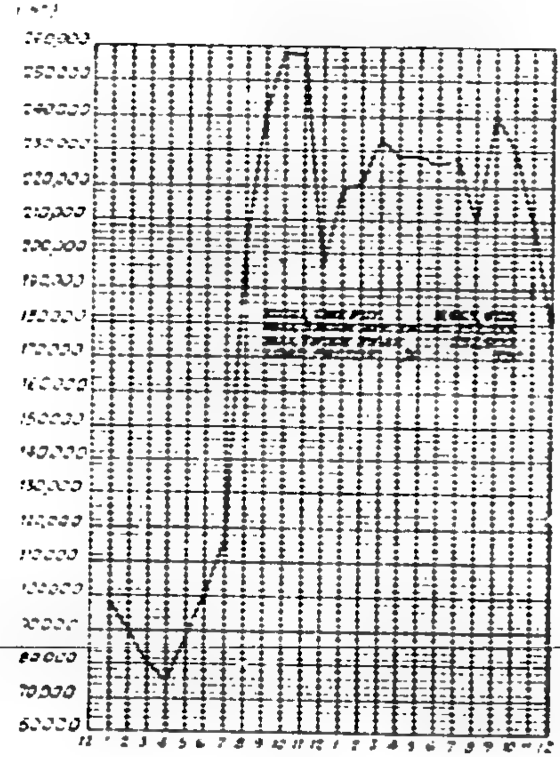

FIG 2

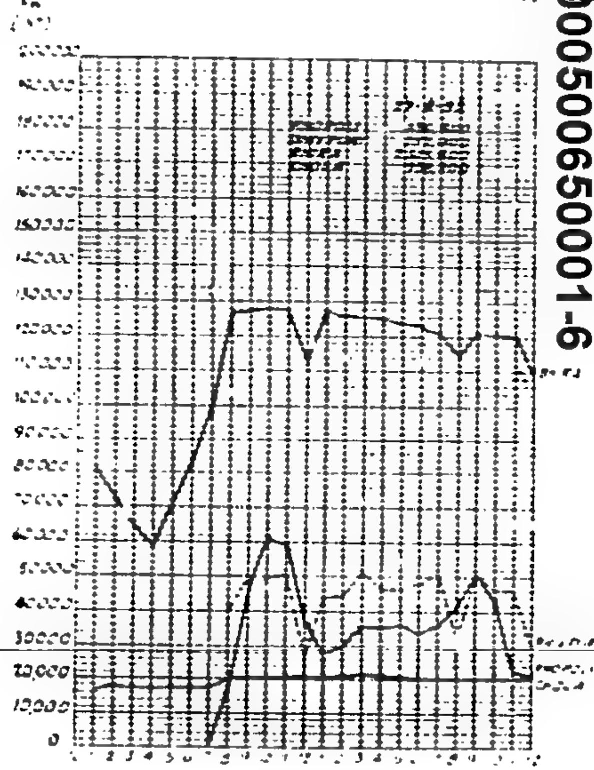

FIG 3

By 1915, the system loads outgrew the resources of hydro energy. [illegible] uncertain factors, no major power scheme was immediately undertaken. Shortages continued to increase during the post-war period. For reasons of expediency, extensions were planned to augment the thermal capacity of Chola to about 118,000 KW, and to realise certain benefits of steam-hydro coordination an additional hydro unit of 22 MW was installed at Bhira, entirely for the purpose of peaking with the additional thermal plant. This would enable heavier loads to be carried by the interconnected system, but even so the generating capacity would barely be sufficient to meet the expected system load of about 330 MW in 1955.

Plans for further development in this region include immediate construction of a new Thermal Plant of 100 MW capacity, and early commencement of a large hydro electric Project, viz., the Koyna, with a firm potential of 240,000 KW. The addition of thermal plants in an area far removed from sources of coal, and rich in hydro, was due to the fact that thermal plants could meet the pent up demand of the area, considerably earlier than hydro.

As long as hydro energy resources are insufficient to meet the load demands, the best method of carrying the load would be to operate the steam plants at the base of the load curve throughout the year, at the same time permitting utilisation of all the hydro energy available for taking the system peaks. During years of good rainfall this would mean that the Bhira Station – short of storage as it is – would find a place at the base of the load curve, during the monsoon season. Operating thermal plants at the base, would ensure that thermal plant installation is reduced to a minimum.

As explained elsewhere, this area has abundant resources of hydro power, which can be utilized in convenient stages. When these resources are made available, the thermal plants would no longer operate on the system base. They would be replaced by hydro, in order to lower generation costs, and the steam stations depreciated to an extent, would then be used on system peaks to their maximum capacity value.

III. DISTRIBUTION OF THERMAL AND HYDRO RESOURCES OVER THE COUNTRY

A brief reference needs to be made to the distribution of hydro and thermal resources over the country, and their present and future status of development, in order to appreciate the importance of the subject to India's power development programme.

India's resources of good quality coking coal for metallurgical purposes are not only limited, but are concentrated mainly in the north eastern part of the country, comprising the states of Bihar and West

Bengal There is a relative abundance of high-ash content coal, both in [illegible] located region of Madhya Pradesh.

Existing thermal stations rely on the use of good quality coal often transported over hundreds of miles. Damodar Valley Corporation's Bokaro Plant has set up a trend towards the use of the more abundant high-ash content coal, at the mouth of the coal pits, using high steam pressures and temperatures, and future development in this field is expected to follow this pattern. Thermal power would be cheapest in and around the coal fields of Bihar, West Bengal and Madhya Pradesh. With the present day cost of plant and equipment, the cost per KW, Hr. of thermal power varies from 0.42 to 0.7 of an anna, depending upon the size of the power station and its distance from the coal producing centres.

Hydro resources are generally more evenly distributed, although the cost of development of these resources, varies widely from region to region, and are controlled by entirely different factors. High head water power resources constitute the cheapest source of hydro power in this country, and these are dotted along the high ridge of the Western Ghats from Bombay to the Cape; in a restricted area of the Eastern Ghat Ridge, near the boundary of the states of Madras and Orissa and near the foothills of the Himalayas. Over 5 million KW of high-head power can be obtained from the mountain streams of the Western Ghats alone, of which the present utilisation is less than 8%. Low and medium head water power resources of considerable magnitude are discernible, all along the course of the main rivers draining the central plateau viz. the Tapti, the Narmada, the Mahanadi, the Godavari and Krishna rivers. Their development requires the construction of huge civil works, and can be carried out most economically on the "multiple purpose" pattern, though the extent of development of this enormous potential, and the value of this source of power, will be governed by considerations of irrigation, flood control, navigation, etc. Enormous resources of hydro power are strung along the foothills of the Himalayas, the huge potentials at Bhakra (600,000 KW) and Kosi (1.8 million KW) being indicative of the proportions of works involved.

IV. CONDITIONS GOVERNING THE EXTENT OF CO-ORDINATION POSSIBLE IN THIS COUNTRY

It is well known that the greatest benefits are obtained when developments of steam and hydro stations are properly coordinated at each stage. This in turn depends on the cost of thermal power, and upon a variety of natural conditions relating to stream flow and topography which determine the cost of hydro development.

The general pattern of stream flow during a year is similar all over the country, being characterised by a short spill of heavy river discharge during the summer followed by a long period of almost negligible flow.

The streams that drain the central plateau of India depend entirely on [illegible] is both brief and intense, the dry season flow of these streams reducing to a trickle. The dry period flow of the Himalayan rivers is augmented by melting snows, but the ratio between the maximum and minimum river flows is still very considerable. Some of the streams notably the small rivers of South India, derive some inflow from the winter monsoon as well as the summer monsoon, and this tends to even out the enormous variations in river flow to that extent.

In addition to these large seasonal variations during a year, the total yield of the catchments varies considerably, from year to year depending on the strength of the monsoon. The ratio of maximum to minimum annual yield generally varies between 2 and 1. Run-of-the-river schemes are therefore ruled out of consideration for major developments. Any hydro electric scheme of importance has to provide sufficient storage both to even out seasonal variations, and where possible to carry over the excess yield in years of good rainfall for use during lean years. Hydro-electric schemes in this country, as independent firm producers of power or as partners in a combined system, have therefore to be considered on the basis of the amount of regulation that can be afforded. The subject is therefore considered under heads which differ only in the degrees of regulation afforded but brings out the essential principles involved.

Where storages are sufficient to permit complete regulation to even out both annual and seasonal variations of river flow, the entire average yield of the catchment can be used to generate firm power at the load factor assigned to the plant. In general this is possible only in a few cases, usually high head projects where the quantities of water to be regulated are small, and submergence of lands by reservoirs offers no great problem. Some of the rivers flowing from the Western Ghats of Peninsular India for instance, the Koyna, the Kalinadi, the Sharavati, and the Barapole rivers lend themselves to development of this sort. Topographically dam sites are suitable for providing adequate storage, and since the overall economy is overwhelmingly assured by the high heads available, there is room for incremental increases in the investments on storage. In such cases the entire hydro resource becomes a firm asset and the question of increasing the load carrying ability of hydro by operations in conjunction with thermal stations does not arise until the firm power potencial has been fully utilized. It is expected that the cost of power which can be developed in convenient stages from these schemes, will be of the order of 0.1 of an anna per KW hr. It is obvious that thermal plants should be considered at a stage when hydro resources are exhausted, and then assigned to the base of the load curves, hydro capacity being suitably augmented to absorb the system peaks.

In cases where topographical conditions limit the storage, say, to the extent required for evening out only the seasonal variations, the "firm" capacity of the hydro plant has to be assessed under conditions that would

obtain during a year of low rainfall. Quite obviously a considerable [illegible]ould be available during years of average and better-than-average rainfall. When such schemes are operated in conjunction with thermal plants of suitable capacity, the hydro plants can be operated at the base of the load curve during periods of abundant flow and during the dry periods the position can be reversed. In order to permit this, sufficient hydro plant will have to be installed to enable generation of a good portion of the secondary power available. It should be remembered that till such time as the secondary energy is firmed and sold as such, the investment on the additional generating facilities intended for generating secondary power are virtually locked up. Adoption of this method of planning therefore presupposes existence of a substantial load that could utilise the combined firm power. A number of schemes under planning or construction in this country at the present time — all of them medium and low head schemes, e.g.

(200,000 KW), Hirakud   (600,000 KW), Bhakra   (362,000 KW), Ukai   (330,000 KW) Punassa,

etc., fall under this category. The firm power of these schemes is considerably in excess of immediate load requirements in the surrounding regions. In spite of the fact that construction of these projects enables the generation of secondary energy very considerably in excess even of the huge "firm" capacity, the possibilities of generating the power and firming it up with the aid of thermal power may have to be "sealed", so to speak, merely because there is no ready outlet for the power. However, in cases where the investment on additional generating facilities is not considerable, planning could be on the basis of future co-ordinated operation with thermal plants, and these possibilities left open.

There are several instances in this country of low head schemes, where the effective storage available — limited either due to topographical conditions or due to the over-riding requirements of flood control, irrigation, etc. — *is not even sufficient for complete regulation of seasonal variations during a critical year.* The Damodar Valley Corporation Dams, for instance, intended as these are largely for flood control, enable the utilisation of only a part of the total flow for generation of power. Further, the discharge is often controlled by the requirements of irrigation. In such cases thermal plants must form an integral part of the system from the inception, in order to obtain maximum benefit.

It may be recalled that as independent sources of power, only a fraction of the energy resources of D.V.C.'s hydro plants could be sold at the high rates for firm power. But with the installed capacity increased to enable the generation of considerable amount of secondary energy and consequent firming up with Bokaro's thermal plant, almost all the secondary energy at the site has been converted to firm power and assessed at a high rate of return. The enhanced returns go a long way towards en-

suring the financial soundness of the main scheme. Where conflicting in- [illegible]s restrict the flexibility of control of hy- dro- — one of its greatest assets — steam-hydro coordination is the only way of rescuing the power aspect.

One of the earliest instances of steam-hydro coordinated operation in this country was on the Ganges Grid, where the sources of hydro power in this area, make use of a series of 'drops' on the extensive existing system of irrigation canals. The flow in these canals follows the pattern of irrigation releases, and no facilities exist for regulation of any sort. Although in the initial stages the power was utilised largely for tube-well pumping, the extension of services necessitated firming up the power with steam stations. These hydro-plants, for full utilisation of hydro resources, have had to run on the base of the load curve all through the year, and steam stations used for peaking. Although this is a relatively uneconomic use of steam stations, overall economy springs from the fact that the hydro power on these projects is generated at comparatively low costs. Incidentally, it would be of interest to note that hydro power from canal power houses can also be firmed up by operating them in conjunction with hydro schemes backed by storage. Hirakud and Bhakra-Nangal are examples of application of this principle.

V. CONCLUSION

While considerable benefits accrue from the interconnected operation of steam and hydro systems built up to capacity independently, maximum benefits can be realised only when the development of power systems is planned on integrated basis. The emphasis that should be laid varies from region to region. India has the advantage that the great developments under way now, and those being planned for the future, have been planned from the start in order to ensure maximum benefits at all stages of development.

VI. SUMMARY

The coordinated operation of hydro and thermal plants is clearly defined. The problems involved in coordinated development are explained on basis of two examples -- Damodar Valley Corporation and Tata Power System.

2. With regard to Damodar Valley scheme, during the Monsoon period, Konar, Panchet Hill and Maithon Hydro-stations would operate on the base of the load curve (the maximum demand on all the three being about 120,000 kW) and two - 50 MW thermal sets at Bokaro thermal station would carry the peaks during this period (not exceeding 100 MW); and during the dry period Bokaro would run at the base of the load curve at a capacity of 100,000 kW and hydrostations would meet the peaks to the required extent.

With regard to Tata Power System, (with total maximum demand on the [illegible] 25[illegible]00 kW) as long as hydro energy resources are insufficient to meet load demands the thermal station at Chola would operate at the base of load curve throughout the year and all available hydro energy would be utilized for the system peaks; and during years of good rainfall Bhira Hydro station would run at the base of the load curve during the Monsoon period.

3. The distribution of Thermal and Hydro power resources in India is reviewed.

4. The conditions governing the extent of coordination possible in India are fully discussed. The essential cases brought out are as follows:

(a) Where storages are sufficient to permit complete regulation to even out both annual and seasonal variations of river flow, the entire average yield of the catchment can be used to generate firm power at the load factor assigned to plant.

(b) Where topographical conditions limit the storage to the extent required for evening out only the seasonal variations, the "firm" capacity of the hydro plant has to be assessed under conditions of low rainfall year.

(c) Where effective storage available is not even sufficient for complete regulation of seasonal variations during a critical year, thermal plants must form an integral part of the system from the inception to obtained maximum benefit.

Résumé

L'opération coordonnée d'installations hydrauliques et thermiques est clairement définie. Les problèmes compris dans le développement coordonné sont expliqués en prenant pour base deux exemples: le système de la "Damodar Valley Corporation" et le "Tata Power System".

2. En ce qui concerne le fonctionnement de la "Damodar Valley", pendant la période de la mousson, les centrales hydrauliques Konar, Panchet Hill et Maithon fonctionneraient sur la base de la courbe de charge (la demande globale maximum des trois centrales étant d'environ 120.000 kW), et deux générateurs thermiques de 50 MW a la centrale de Bokaro entreraient en fonction aux moments des fortes charges (n'excédant pas les 100 MW); et pendant la saison sèche, Bokaro fonctionnerait sur la base de la courbe de charge à une capacité de 100.000 kW et les usines hydrauliques feraient face aux fortes charges.

En ce qui concerne le "Tata Power System" (avec une demande totale maximum sur le système d'interconnection d'environ 258.000 kW), la centrale thermique de Chola fonctionnerait pour la base de la courbe de charge pendant toute l'année tant que les ressources en énergie hydraulique seraient insuffisantes pour répondre aux demandes de charge,

et toute l'énergie hydraulique disponible serait utilisée pour les pointes [illegible] de pluies abondantes, la centrale de Bhira s'occuperait de la base de la courbe de charge correspondant à la saison de la mousson.

3. L'auteur étudie la distribution des ressources d'énergie thermique et hydraulique dans l'Inde.

4. Les conditions régissant le degré de coordination possible dans l'Inde sont discutées en détail. Les principaux ceas examinés sont les suivants:

(a) Dans les cas où l'eau accumulée est suffisante pour permettre un contrôle complet afin de régulariser les variations saisonnières et annuelles du débit du fleuve, la production moyenne générale du bassin de captation peut être utilisée pour fournir de l'énergie sûre ("firm power") au facteur de charge déterminé pour la centrale.

(b) Dans les cas ou les conditions topographiques limitent l'accumulation d'eau à la quantité désirée pour régulariser seulement les variations saisonnières, la capacité sûre de la centrale hydraulique doit être déterminée par les conditions d'une année sèche.

(c) Lorsque l'accumulation réelle disponible n'est même pas suffisante pour régulariser complètement les variations saisonnières pendant une année critique, les centrales thermiques doivent former partie du système dès le début, pour obtenir les meilleurs résultats.

RESUMO

A monografia define, claramente, a operação coordenada de usinas hidro e termo-elétricas. Os problemas contidos no desenvolvimento dessa operação coordenada são explanados com base em dois exemplos — o sistema "Damodar Valley Corporation" e o "Tata Power System".

2. Relativamente ao sistema do Vale Damodar, durante o período das monções, as usinas hidro-elétricas de Konar, Panchet Hill e Maithon operariam na base de curva de carga (a máxima exigência em tôdas três sendo de cêrca de 120.600 KW) e dois conjuntos termicos de 50 MW na usina térmica de Bokaro tomariam conta das pontas de carga (não excedente de 100 MW); e, durante o período das sêcas, Bokaro trabalharia na base da curva de carga com uma capacidade de 100.000 KW, e as usinas hidro-elétricas se ocupariam das pontas.

Em relação ao "Tata Power System" (com uma solicitação máxima no sistema interconectado de cêrca de 258.000 KW), enquanto os recursos hidráulicos fôssem insuficientes para atender à solicitação, a usina termo-elétrica de Chola operaria durante o ano todo na base da curva de carga,

e tôda a energia hidro-elétrica seria utilizada para as pontas do sistema; durante os anos de chuvas abundantes, a usina hidro-elétrica de Bhira operaria na base da curva de carga, no período das monções.

3. O autor estuda a distribuição das fontes de energia térmica e hidráulica na India.

4. As condições que regulam o grau da possível coordenação na India são discutidas pormenorizadamente. Os casos principais examinados são os seguintes:

(a) Nos casos em que a água acumulada é suficiente para permitir a regularização completa das variações sasonais e anuais da descarga do rio, a produção média geral da bacia de captação pode ser usada para produzir energia firme com o fator de carga determinado para a usina.

(b) Nos casos em que as condições topográficas limitam a acumulação de água ao necessário para regularizar apenas as variações sasonais, a capacidade firme da usina hidro-elétrica deve ser determinada para as condições de um ano sêco.

(c) Nos casos em que a acumulação efetiva disponível não é suficiente nem mesmo para regularizar completamente as variações sasonais durante um ano crítico, as usinas termo-elétricas devem ser parte integrante do sistema desde o começo para se obterem os melhores resultados.

CONFERÊNCIA MUNDIAL DA ENERGIA
WORLD POWER CONFERENCE

Asunto 1.1

REUNIÃO PARCIAL
SECTIONAL MEETING
Rio de Janeiro — 1954

ACKERMAN (A.J.)
Estados Unidos

PLANNING OF THE ELECTRIC POWER INDUSTRY IN BRAZIL

By ADOLPH J. ACKERMAN
Consulting Engineer — Madison, Wisconsin, U. S. A.
UNITED STATES NATIONAL COMMITTEE

PRESENT POWER CRISIS IN BRAZIL

Brazil has in recent years been confronted with a nation-wide shortage of electric energy, which in some regions has reached the status of a power crisis.

Any effort to appraise the present power situation, and to formulate a program which would produce the desired abundance of power within a reasonable period of time, requires, first of all, a definition of a practical point of view from which to make such an appraisal.

For this purpose no better statement can be made than the following, which is paraphrased from the words of one of America's leading planners * of public facilities, in the following:

> It would be pleasant if this problem could be solved by some inventor working in an obscure laboratory or office with an entirely new formula, or a unique amalgam of ingenious methods, economics and budgeting, immediately recognized by experts and instantly accepted by the public. In such contexts, the talented amateur, unhampered by experience or responsibility, dreams of a device which at one stroke through one central agency can finance and build, without prolonged debate, stultifying compromises and division of authority, a country-wide program and guarantee its early completion. Even if such a solution were theoretically possible, it would involve so many dangers and bad precedents, so much con-

* Robert Moses on "Planning of Highways".

centralization of power, so manifest a violation of states rights, [illegible] and representation, that it would never get beyond the paper and prospective stage. Democracy, as we practice it, is a tedious and irritating business not to be confused with dictatorial five-and ten-year plans based on forced labor and liquidation.

Nothing much, therefore, will come from wishful thinking and over-simplification. It is much more likely that the answer for the next decade at least will be a concerted, unremitting attack on established, orthodox lines from many quarters, requiring the cooperation of innumerable public officials and industrial experts and laymen, technicians and administrators, consumers and builders, labor and capital, bankers and borrowers, advertisers and readers. Persistent, largely undramatic daily work directed toward agreed, realizable, limited objectives is what we need.

No useful purpose would be served by a belated attempt to fix responsibility for the discrepancy between power supply and demand. It is the future, not the past, that counts. The objective is to catch up on power development and keep pace with an increasingly industrialized civilization. How to accomplish this within available abilities and means under normal conditions -- this is the task.

PRESENT STATUS OF BRAZIL'S ELECTRIC POWER SUPPLY

The general program of electrification in Brazil is still in its infancy. The present is therefore an important time for appraising basic problems and fundamental policies relating to power supply, and for proposing ways and means for future development which will best serve the country's interests.

Of greatest importance at this stage is the adoption of long-range policies and technical standards under which the future electrification program can progress most effectively.

Present Status of Power Supply

Some of the significant facts concerning Brazil's power supply are summarized in the following:

1. As recent as 1946, over 80 per cent of Brazil's total energy sources came from the burning of wood, whereas hydroelectric power provided less than 2 per cent.

2. Brazil's coal industry is in its infancy and there is no adequate supply for large-scale or widely-dispersed development of steam power.

3. Brazil's potential petroleum resources have as yet not been de[illegible] for power development must be imported which adversely affects Brazil's balance of exchange.

4. The country is rich in hydroelectric potentialities which have been estimated at 16,000,000 Kilowatts.

5. The principal region of economic development extends from the State of Minas Gerais to Rio Grande do Sul. Of Brazil's total population of 49,000,000, 58 per cent live in this region. Its cultivated area represents 73 per cent of Brazil's total cultivated area. This region contains 70 per cent of the country's hydroelectric potentialities.

6. Brazil's installed capacity is about 2,000,000 Kilowatts (about the same as the total in the State of Wisconsin) of which 70 per cent is hydroelectric power.

7. The electric power supply comes from 2,000 power plants of which over 1,700 have capacities of less than 1,000 kw each.

8. The total energy produced by public utilities in 1951 was nearly 8,000,000,000 kwh; 83 per cent of this was produced by two foreign-owned public utility systems.

9. [illegible] the power development has taken place in three states [illegible] and Minas Gerais. Except for a few other [illegible] more than 50,000 kw, the installed capacity of most of the remaining states is substantially less.

10. Brazil has embarked on a nation wide program of public power development. Since World War II seven Federal and State Power authorities have been organized.

Financing

11. Most of the generating, transmission and distribution equipment for public utility systems is imported - also, much of the consumer equipment. Annual production of electrical goods in Brazil was equivalent to US$ 30,000,000 in 1950. Efforts are being made to increase the output of locally manufactured goods.

12. In 1951, the invested capital in public utility systems was in round numbers Cr$ 10,000,000,000 which is equivalent to between US$ 500,000,000 and US$ 750,000,000, depending on the value of the cruzeiro during past years.

13. Currently planned power developments which are expected to come into operation during the next five years, 1953-1958, will provide 1,600,000 kw of additional capacity, or 80 per cent more than existing capacity. The estimated cost of this program is around Cr$ 16,000,000,000 (equivalent to US$ 800,000,000).

14. The local funds will come chiefly from reinvestment of earnings and accumulated reserves, sale of stock in the local power companies to prospective consumers and other investors, and from electrification taxes which are designed to support the state and federal projects.

15. About one-third of the total capital required is for importation of electrical machinery and equipment which is expected to be financed through loans granted by the World Bank, Export-Import Bank and similar sources.

16. Since 1948, foreign loans for electric development granted by the World Bank and the Export-Import Bank amount to a total of US$ 190,000,000.

Technical Matters

17. Standardized transmission voltages and interconnected systems have not been developed. Standardization of frequencies is becoming increasingly important.

18. Due to the lack of local fuel, Brazil must rely on future development of hydroelectric power. North American practice of combining steam and hydroelectric power for most efficient system operation is not applicable to Brazil under present circumstances.

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19. In an attempt to remedy the shortages of power in industry, [illegible] plants are being installed. It is estimated that since the end of World War II, about 200,000 kw of such equipment has been imported.

20. Small thermal plants and hydroelectric units are needed in many of the interior communities to help develop the country agriculturally to a point where Brazil can eventually feed herself, and to reverse the present population drift toward the larger cities.

21. The shortage of engineers and technical personnel in Brazil is even more serious than the present shortage of electric energy.

POWER SUPPLY FOR FEDERAL DISTRICT AND STATE OF RIO DE JANEIRO

The Federal District and the central and western part of the State of Rio de Janeiro over the years have had an abundant supply of electric energy and an ample supply of power is in prospect until about 1960.

The northern and western parts of the state are being served by the Rio de Janeiro Tramway, Light and Power Company, a subsidiary of Brazilian Traction, Light and Power Company of Toronto, Canada. This is largely a hydroelectric system operating at 50 cycles. It had an available generating capacity before November, 1953, of 381,000 kw, the principal power plants being the Fontes plant at Lajes with a capacity of 154,000 kw, and the Ilha dos Pombos plant with a capacity of 140,000 kw. In November, 1953, the first unit of the new Forcacava underground power development was placed into service. This plant is designed for a capacity of 330,000 kw, operating with water diverted from the Paraiba River through the recently completed Paraiba-Pirai Diversion Project. Provisions have been made for ultimately adding a further 360,000 kw at this site.

The power company's Lajes Reservoir also serves as the principal reservoir for the domestic water supply for the city of Rio de Janeiro.

Across the bay from Rio de Janeiro, the territory is served by Cia. Brasileira de Energia Eletrica, a subsidiary of American and Foreign Power Company. This company at present has a generating capacity of 34,000 kw and operates at 60 cycles. A new steam plant with an initial installation of 10,000 kw is expected to go into operation in 1954. Because of the limited area in which the company operates it has small opportunity to develop additional sources of hydroelectric power.

POWER SYSTEM OF SÃO PAULO LIGHT AND POWER COMPANY

The largest power system in Brazil is that of the São Paulo Light and Power Company, Ltd., a subsidiary of Brazilian Traction Light and

Power Company of Toronto, Canada. This system has a capacity of [illegible] cycles; the most important power plant is the high head development at Cubatão with a capacity of 171,000 kw.

The company has been the primary factor in the tremendous growth of the City of São Paulo and its great industrial expansion. Over the past twenty years the growth of energy sales has averaged 11.2 per cent per year.

During the past several years the company has not been able to meet the new demand and a very serious power shortage currently exists in its territory. A new hydroelectric plant at Cubatão with an ultimate capacity of 390,000 kw was started in 1951 and is scheduled for initial operation in 1956 with the first of four 65,000 kw units.

In 1952 the company also started construction of the Piratininga steam plant containing two 80,000 kw generating units which are to go into operation late in 1954 or early 1955.

BRAZILIAN OPERATING SUBSIDIARIES OF AMERICAN & FOREIGN POWER COMPANY

The American and Foreign Power Company, through its wholly-owned subsidiary has a controlling interest in 15 operating companies and a management company in Brazil. These companies are located in various cities along the eastern coast from Natal in the north to Porto Alegre in the extreme south. The combined generating capacity of its power plants is 251,000 kw.

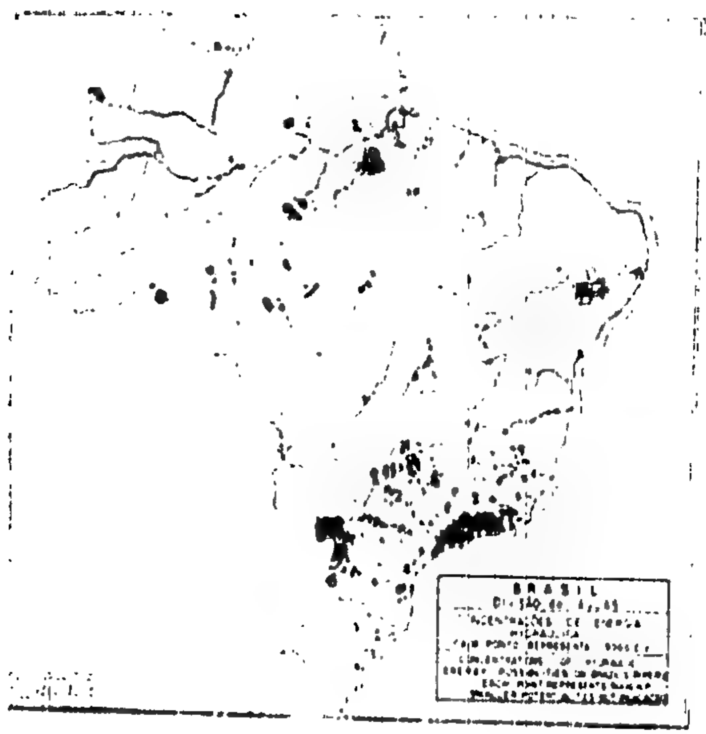
Annual growth in demand is currently at the rate of 10 to 12 per cent per year in most of the service territories.

The most important subsidiary, Cia. Paulista de Força e Luz in the State of São Paulo, has a total generating capacity of 90,700 kw. In addition to several new smaller plants, this company has embarked on an expansion program involving the construction of a large dam on the Rio Grande River in the northern part of the state. Initially, 80,000 kw will be installed, but the site can be developed to a maximum of 100,000 kw. This will contribute substantially to the development of the interior of the state.

The local subsidiary in the State of Rio de Janeiro is also expanding its system, as previously mentioned, by adding a 10,000 kw steam plant to its present system capacity of 33,000 kw.

In the service territories of the States of Minas Gerais, Pernambuco, Bahia and Rio Grande do Sul the supply of new power is being taken over by federal and State power developments. This is leading to discontinuation of further expansion plans by the local subsidiaries, except in their distribution systems. The subsidiaries plan to buy power from these publicly owned projects and distribute it to the consumers.

One of the most important and rapidly growing territories is in [illegible] the subsidiaries is serving the capital city of Curitiba and surrounding communities. Its present generating capacity of 22,000 kw is being expanded by the construction of a hydroelectric plant with an additional capacity of 20,000 kw. However, the State is also attempting to deal with the problem of developing a general electrification program.



In summary, the American and Foreign Power Company has a program of expansion for the period of 1952 to 1956 which will add a total of 176,500 kw of new generating capacity to the various subsidiary systems.

POWER DEVELOPMENT BY THE STATE OF SÃO PAULO

In 1950 the State of São Paulo embarked on a hydroelectric program of its own. The first step is the Salto Grande project on the Paranapanema River in the western part of the state. Construction of this project was started by the state-owned Sorocabana Railroad, primarily to provide

power for its railroad electrification. The project has been designed for [illegible] kw and is scheduled for completion by the end of [illegible]

ELECTRIFICATION PROGRAM OF THE STATE OF MINAS GERAIS

Due to the inflation and inadequacy of power rates and low returns on investments, private utilities have not provided the energy needed by the various industries and municipalities of this state. The State government has therefore embarked on a comprehensive program of electrification.

In 1950 the state of Minas Gerais had 439 power plants, large and small, with an aggregate capacity of 218,000 kw. Many of these plants serve private industries such as mines, factories and mills. The 439 plants have 359 different owners. Only four plants have capacities in excess of 5,000 kw.

Cia. Fôrça e Luz de Minas Gerais (subsidiary of American and Foreign Power Company) serves the city of Belo Horizonte and nearby communities with a generating capacity of 21,721 kw and 9,000 kw of purchased power from the state-owned power system.

During 1949 to 1951 the state adopted various laws to formalize its future program of electrification under state sponsorship. The principal holding company representing the state's interest is known as CEMIG (Centrais Elétricas de Minas Gerais, S.A.). This company is designed to establish, manage, finance, provide technical, accounting, legal and executive assistance to its subsidiaries which are "mixed" companies of regional character, whose purpose is to develop the electric power and related transmission and distribution systems in their respective zones of influence.

At present the state owns three small hydro developments, and has under construction the Itutinga project (36,000 kw) and Santo Antonio (50,000 kw initial).

Future plans are being developed in an orderly manner and sound technical standards are being adopted for a continuing expansion program.

ELECTRIFICATION IN THE STATE OF PARANÁ

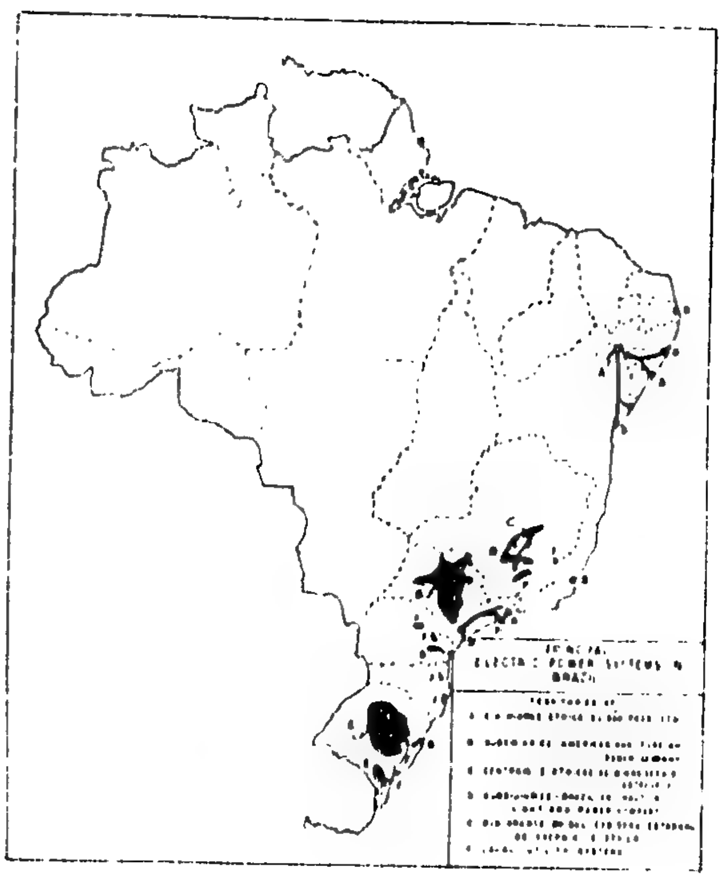
This state is rapidly growing in importance but at present has only 55,000 kw of installed generating capacity, made up of 75 separate systems. Paraná has over 1,000,000 kw of hydroelectric potential, and various plans are currently under consideration for organizing a long range program of development.

STATE OF SANTA CATARINA

This state has a relatively small generating capacity, 15,000 kw. Future plans for electrification could to advantage be integrated with the programs of the adjacent states of Rio Grande do Sul and Paraná.

This state is the principal source of coal for Brazil but the quality is relatively poor. Only 27 per cent of the presently mined coal is recoverable as suitable for commercial disposal. This accounts for the high cost of local coal which is greater than the cost of imported coal.

At present, very little is known about the geology and available coal reserves.



STATE OF RIO GRANDE DO SUL

The total generating capacity in Rio Grande do Sul in 1952 for public utility service was 80,000 kw. In addition, there was a total of about 100,000 kw of generating capacity installed in numerous factories mostly located in the interior of the state. The principal private utility (a subsidiary of American and Foreign Power Company) serves the capital of Porto Alegre with a steam plant rated at 24,600 kw capacity.

The State Electrification Commission of Rio Grande do Sul was organized immediately after World War II and is carrying out a well planned program of electrification. As a first step it installed emergency diesel generating plants in various parts of the state, particularly in the rural areas, along with small hydroelectric projects. As a second step larger projects were, and are now, under construction; a good program has been planned for future development of still larger projects which are now becoming economically justified.

In the first stage a total of 62,000 kw were installed. The second stage will involve the installation of 286,000 kw of new capacity.

The program is being financed through an electrification tax; the foreign imports are financed by a loan of US$ 25,000,000 from the International Bank for Reconstruction and Development.

PAULO AFONSO PROJECT ON SÃO FRANCISCO RIVER

The Paulo Afonso project is being constructed by the Federal Government which is providing all of the local funds. The imported equipment, materials and supplies are being financed by a loan from the International Bank in the amount of $15,000,000.

The project is in a remote location and has experienced many difficulties. However, a conscientious effort is being made to do a satisfactory engineering and construction job.

This project, when completed in 1954 with an initial capacity of 120,000 kw, will deliver power over two transmission lines about 400 km long to the cities of Salvador to the south and Recife to the east. The local power companies (subsidiaries of American and Foreign Power Company) which are located in these two cities are expected to buy 80 per cent of the total initial output.

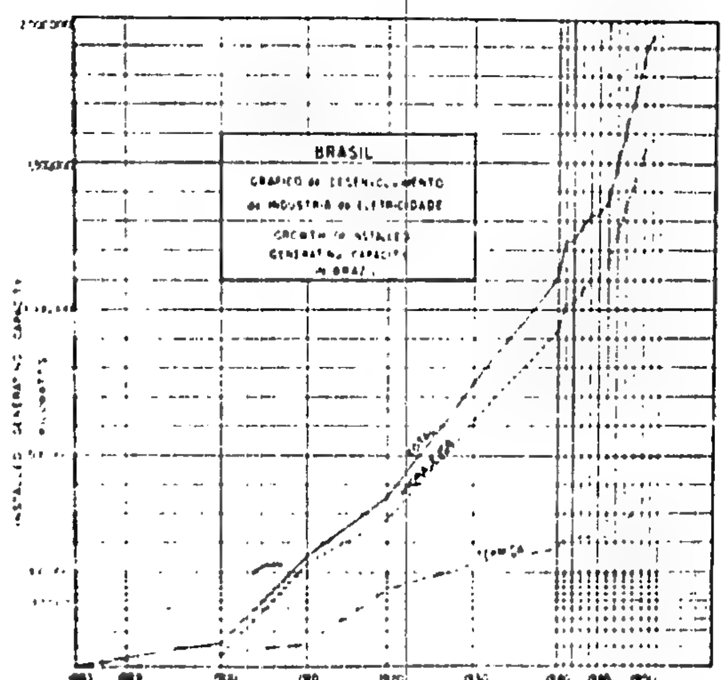
This is one of Brazil's major hydroelectric developments. As the demand for power is increased, the project can be enlarged to 510,000 kw. Furthermore, with adequate upstream storage, it is claimed that further enlargement will be possible.

CONCLUSIONS

Brazil is blessed with great resources of hydroelectric power. The development of these resources is fundamental to the country's future economic growth and industrialization. In this respect the history of

power development in Canada will probably be the best pattern. At [illegible] an installed generating capacity of 11,300,000 h.p. in hydroelectric power. Of the total energy production, 96.5 per cent was hydroelectric power, and only 3.5 per cent was thermal power, because Canada's fuel resources had not (until very recently) been developed.

In Brazil the position of thermal power in the overall economic development is unique. Small power plants which burn locally available wood may be found in all parts of the country. Diesel power plants are



especially useful in interior agricultural regions where water power is not readily available. Large steam plants may in exceptional cases be justified as protection against periodic drouths and to carry peak loads of limited duration.

However, as long as Brazil's oil and coal resources remain undeveloped, and as long as foreign exchange is needed for the importation of essentials other than such fuels, Brazil is confronted with the necessity of developing its hydroelectric resources to the fullest extent possible. A simple formula to keep in mind is the following: The annual payments for imported fuel oil consumed in a steam plant (operating at a high load factor) would be equal to the annual charges on a loan to finance

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[illegible] importation of all equipment for a hydroelectric development whose generating capacity would be [illegible] to 8 times greater than the capacity of [illegible] plants.

SUMMARY

This paper attempts to present an overall perspective of the present status of electric power systems in Brazil, and of current plans for meeting the rapidly growing demand for additional energy. As in the past, maximum reliance must be placed on the development of Brazil's abundant hydroelectric resources. In the face of the present power crisis, all available ability and means are needed for catching up on power development and for keeping pace with an increasingly industrialized civilization. This calls for persistent, largely undramatic daily work directed toward agreed, realizable, limited objectives.

RÉSUMÉ

Le but de cette étude est de présenter une vue d'ensemble de l'état actuel du régime d'énergie électrique au Brésil, ainsi que des projets en cours, visant à satisfaire la demande toujours croissante. Comme dans le passé, il faudra recourir autant que possible aux ressources hydroélectriques abondantes du Brésil. Etant donné la pénurie actuelle d'énergie électrique, il est indispensable de faire appel à tous les moyens disponibles pour rattraper le retard et pour aller de pair avec une industrialisation croissante. Ceci demande un travail persévérant, et sans éclat, dirigé vers des objectifs fixés d'avance, limités et réalisables.

RESUMO

Pretende êste documento apresentar uma vista panorâmica da situação atual do sistema de energia elétrica no Brasil e dos projetos destinados a atender o rápido crescimento da demanda adicional de eletricidade. Como no passado, deve-se dar a máxima importância ao desenvolvimento dos abundantes recursos hidrelétricos do País. Em vista da presente crise de energia é necessário mobilizar todos os recursos disponíveis a fim de conseguir o desenvolvimento da energia elétrica e fazer face a uma civilização crescentemente industrializada. Isso exige trabalho persistente, em grande parte monótono, dirigido a objetivos prèviamente aprovados e de realização plausível.

AUTHOR'S NOTE.

The assignment to present a paper on the important subject indicated by the title is indeed an interesting one, especially to the author, who has, in recent years, had a special opportunity to study Brazil's power systems.

The author feels bold enough to present this paper because six years of residence and service in Brazil has given him a great admiration for the country and its people, and a sense of mutual confidence that these efforts will be accepted in the spirit in which they are offered, namely to contribute to the future progress of Brazil.

CONFERÊNCIA MUNDIAL DA ENERGIA
WORLD POWER CONFERENCE

Titulo 1
Assunto 1 2

REUNIÃO PARCIAL
SECTIONAL MEETING
Rio de Janeiro – 1954

PEATTIE (J. D.)
FULTON (A. A.)
Inglaterra

INTEGRATION OF HYDRO AND THERMAL GENERATION IN GREAT BRITAIN

By J. D. PEATTIE
BSc, FCGI, MIEE, Deputy Chief Engineer (Generation) British Electricity Authority

and A. A. FULTON
BSc, MICE, MIMechE, Chief Hydraulic and Civil Engineer, North of Scotland Hydro Electric Board

BRITISH NATIONAL COMMITTEE

1. INTRODUCTION

The available water power in Great Britain is concentrated in the thinly populated mountainous regions in Scotland and Wales. Thermal stations derive their supplies of fuel from coalfields distributed over the remainder of the country.

In the early 1930's, hydro and thermal public generating stations were interconnected by the 132 kV. Grid network, and development and operation co-ordinated on a national basis. Until 1944, the development of hydro resources was slow, but since then progress has been greatly accelerated.

The object of this Paper is to describe briefly the past development, the present location, extent and results of, and the future plans for, co-ordination of hydro and thermal generation in Great Britain.

2. HISTORICAL BACKGROUND

The first significant integration of water and steam power occurred in 1926 when the Bonnington and Stonebyres run-of-river stations with 16,000 kW. of plant and an average annual output of 80 million kWh. at the Falls of Clyde in Scotland were added to the Clyde Valley Electric Power system to supplement the outputs, amounting to about 200 million kWh. in 1929, of that Company's three interconnected thermal stations.

The construction of the 132 kV. Grid in the early 1930's had a profound effect on development of generating stations in Great Britain. So far as hydro stations were concerned, it widened the basis of planning

[illegible] plant had no longer to be planned to supply in isolation a restricted load. It could be planned to contribute to the general pool of existing and new thermal plant from which consumers over a wide area drew their supplies.

In 1930 and 1932 the Rannoch and Tummel stations, with an installed capacity of 82 MW. and an average annual output of 266 million kWh., were built and connected to the 132 kV. Grid in Scotland and were operated in conjunction with the thermal plant there.

In 1935 the Galloway group of 5 hydro stations were connected to the 132 kV. Grid between Scotland and England and operated in conjunction with thermal plant in Scotland and North West England. They have an installed capacity of 103 MW. and an average annual output of 224 million kWh.

In comparison with the water power potential in Scotland, these developments were small, but progress became more rapid after the North of Scotland Hydro-Electric Board was set up in 1943 for the specific purpose of developing water power as an integral part of the wider plans for the regeneration of the Highlands. As a result, a further 315,765 kW. of hydro plant has been added in North Scotland by the end of 1953. The extent of the progress made with survey, construction and completion at that date is shown in Table 1:

TABLE 1

Scottish Hydro-Electric Development at 31st December, 1953

State of Schemes	Capacity	Estimated Average Annual Outputs
	kW.	Million kWh.
In operation prior to 31st December, 1945	203,890	601
Commissioned between 31st December, 1945, and 31st December, 1953	315,765	675
Under Construction	417,450	1,277
Under Promotion and Survey	278,500	986
	1,215,605	3,539

Progress of hydro generation since 1926 is shown in Fig. 1.

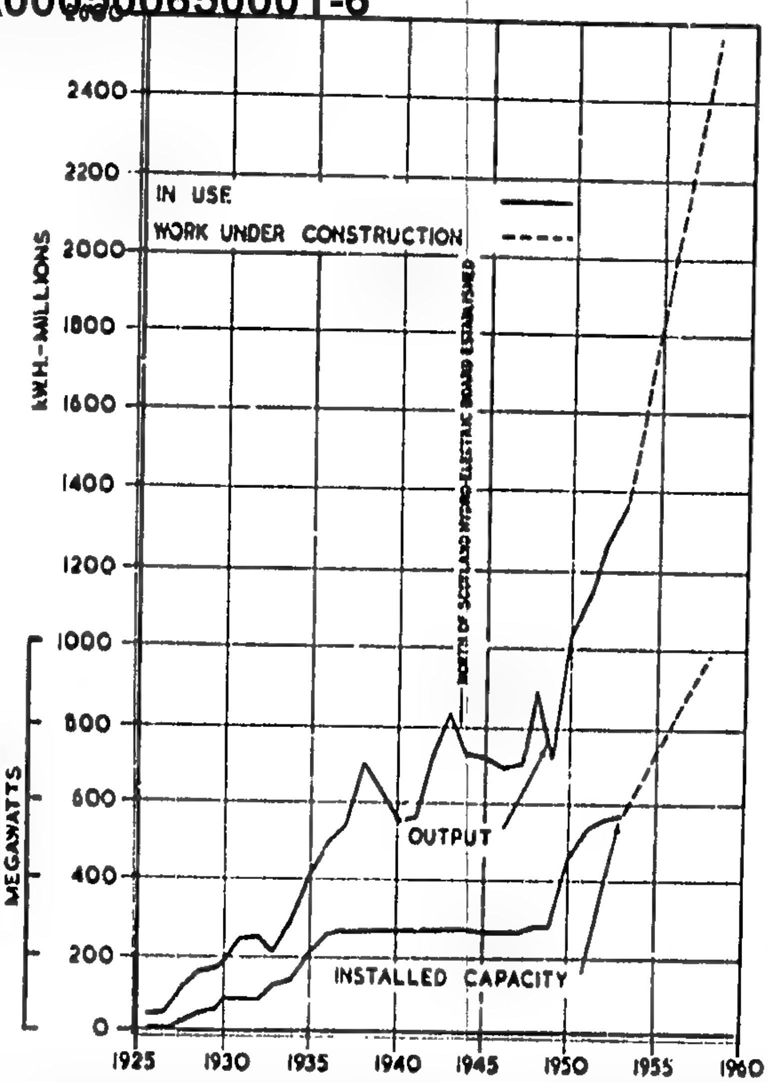

FIG. 1—OUTPUT & CAPACITY OF BRITISH HYDRO STATIONS FOR PUBLIC SUPPLY.

3. GENERAL PLAN OF GENERATION

3.1. *General Background*

Generation for public supply of electricity in Great Britain has been entrusted by Parliament to the British Electricity Authority and the North of Scotland Hydro-Electric Board. Their respective areas are shown in Table 2 and Fig. 2. The North of Scotland Hydro-Electric Board is responsible for Region 1 and the British Electricity Authority for the remaining 7 regions 2 to 8 inclusive.

The North of Scotland Hydro-Electric Board are specifically charged with the development of the hydro-electric resources of Region No. 1 and with the provision of supplies of electricity in that sparsely populated area, a difficult economic task having regard to the low population density of 54 persons per square mile. They are further charged with the duty of supplying to the B. E. A. electricity on a scale to be decided by the Board. The terms under which the supply is given are agreed mutually and the developments are so chosen that the resulting revenue will provide assistance to the Board in their difficult economic task of supplying consumers within their own area.

The British Electricity Authority on the other hand, are required by Parliament to develop and maintain in the rest of Great Britain, with an average population density of 710 persons per square mile, an efficient, co-ordinated, and economical supply of electricity and in so doing to generate themselves and also to purchase, on the terms agreed, the above-mentioned supply from the North of Scotland Hydro-Electric Board.

3.2. *Technical Problem*

The problem facing British Supply Engineers is to arrange for the transport of energy from the sources, its conversion into electrical energy, and for its delivery in that form to the consumers as economically as possible.

Two factors, both largely outside their control, have to be accepted as elements in the general problem of attaining maximum economy. On the one hand, the location and magnitude of energy sources, the coalfields and catchment areas, are matters of geography. On the other hand, location and magnitude of consumers' demands for electricity depend on the distribution of population which, in Great Britain, is concentrated near the coalfields and on trading estuaries.

The contribution from a catchment area depends on geography and the weather. The contribution from each coalfield of fuel for electricity generation is, under present conditions with coal in short

TABLE 2

British Electricity Supply Regions 1952

Name	Control Centre for Generation and Transmission	No. on Fig. 2	Area	Civil Population	Sales in 1952 to consumers in Region	Responsible Authority
			sq miles	'000	Mill. kWh.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
North Scotland	Pitlochry	1	21,600	1,165	747	North of Scotland Hydro-Electric Board.
South Scotland	Glasgow	2	8,197	3,909	3,855	British Electricity Authority
North East England	Newcastle	3	5,049	2,731	2,998	
North West England	Manchester	4	9,082	7,381	8,856	
Mid-East England	Leeds	5	7,546	5,008	5,952	
Central England	Birmingham	6	7,311	6,737	8,567	
South East & East England	London (Regional)	7	12,266	14,644	13,900	
South West England	Bristol	8	17,090	6,886	7,075	
Great Britain	London (B.E.A. National)	—	88,141	48,461	51,950	

[illegible] Coal Board, having regard to all demands for coal. In Great Britain at the moment electricity takes about 17% [illegible].

The locations of coalfields, catchment areas, and trading estuaries are shown in Fig. 2.

3.3. *Function of Grid Interconnection Network*

The 132 kV. and 275 kV. Grids (Figs. 3 and 4) have threfold functions:

(a) They enable peak loads to be met with the minimum national total capacity of generating plant.

(b) They provide transmission capacity for concentration, during off-peak periods, of generation at the stations with the lowest running costs — for example, hydro stations at times of exceptionally heavy run-off.

(c) They provide transmission capacity for transfers at time of peak from catchment areas or from certain thermal stations on coalfields to the load centres.

In broad terms, the 132 kV. circuits interconnect individual generating stations. The 275 kV. circuits interconnect large groups of generating stations.

3.4. *Assessment of Total kW. Generating Capacity required*

Additional generating capacity is provided every year to meet the rising demands of consumers. No attempt is made to provide nationally more than the bare minimum for the winter peak period in each year. Responsibility for providing the total additional capacity is shared between the North of Scotland Hydro-Electric Board and the British Electricity Authority. The North of Scotland Hydro-Electric Board decide the amount of extra hydro capacity which they feel they can provide, having regard to financial and other considerations. The balance of the additional kW. required nationally is allocated by the B. E. A. to sites in their own area (Regions 2-8 inclusive) with a view to securing minimum cost of generation in that area.

3.5. *Choice of Sites for Generating Stations*

Since 1943, the North of Scotland Hydro-Electric Board have planned and carried out practically all hydro development in Great

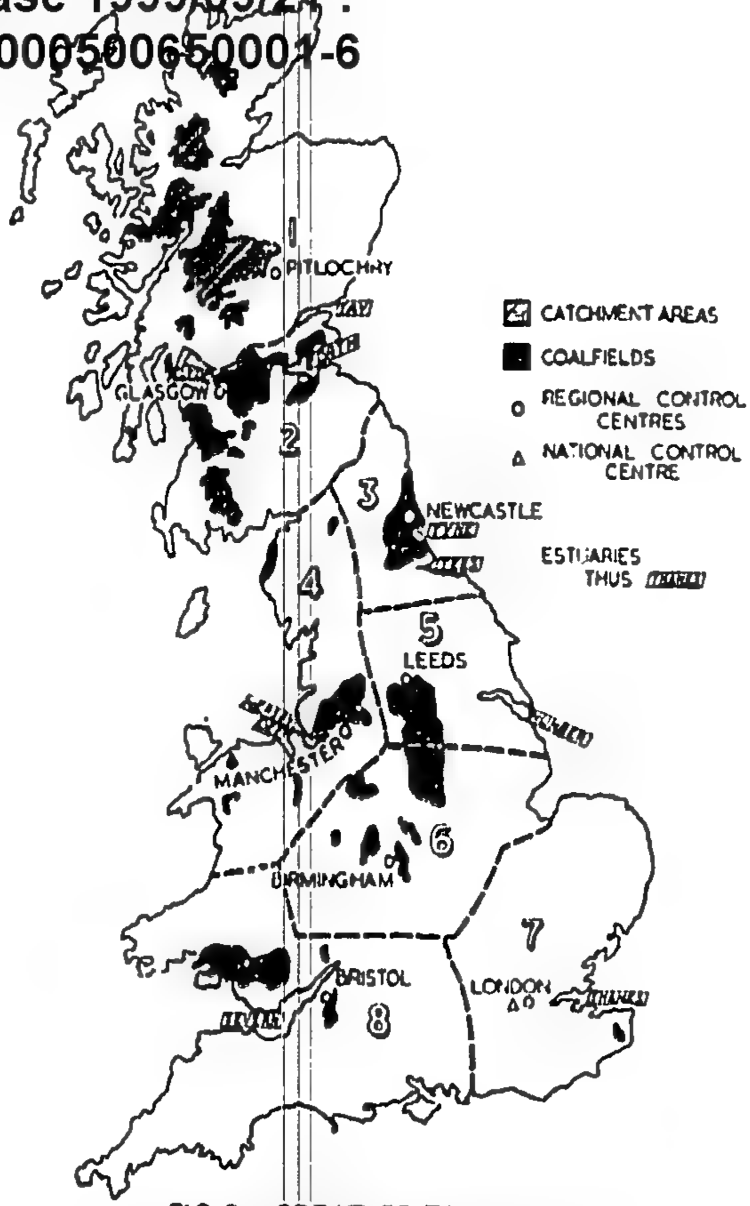

FIG. 2 - GREAT BRITAIN
ELECTRICITY SUPPLY REGIONS 1952
SHEWING CONTROL CENTRES AND TRADING ESTUARIES.

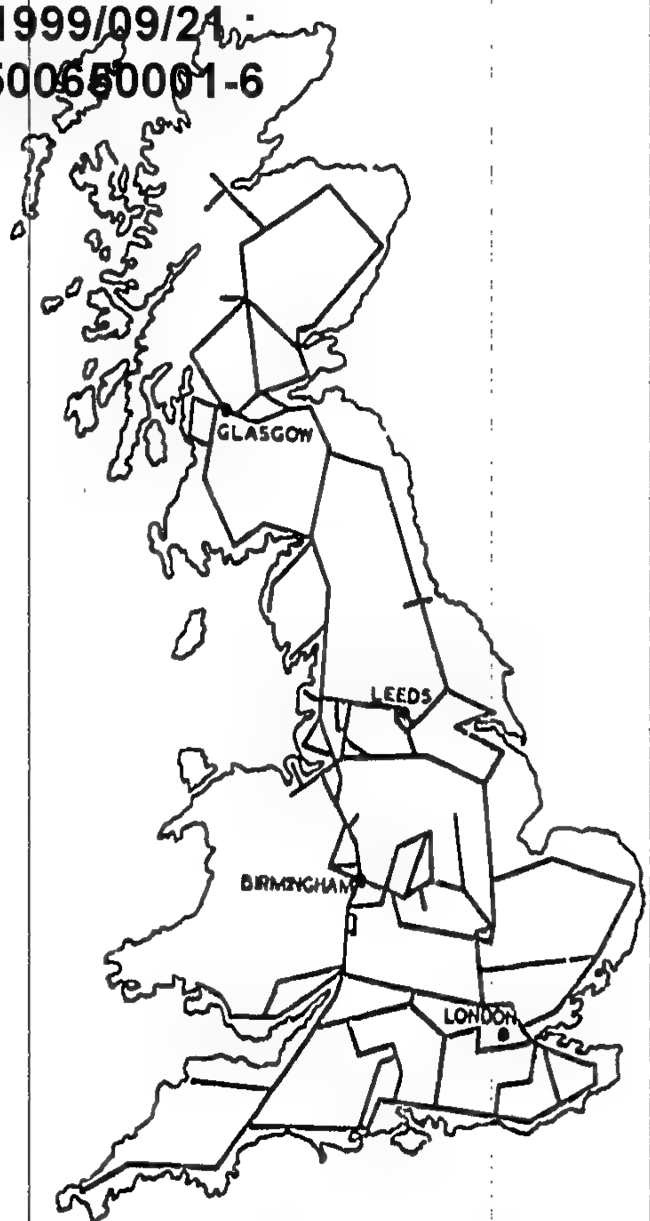

FIG. 3 - 132 KV GRID AT 31.12.52.

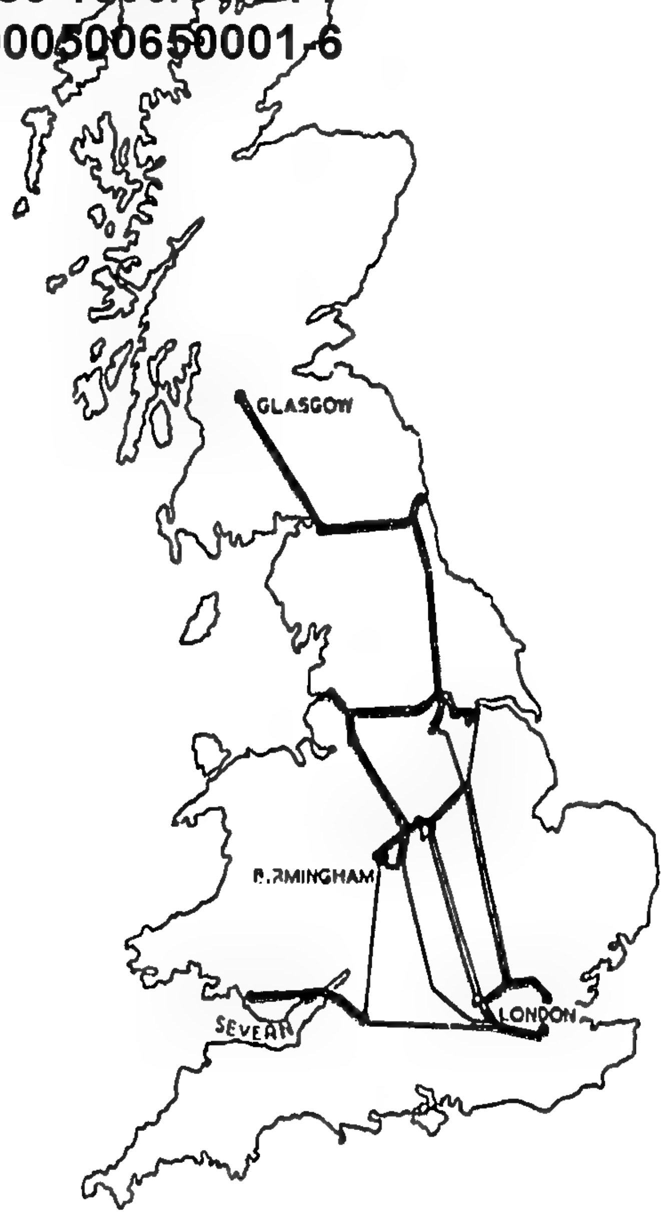

FIG. 4 – 275 kV GRID

Britain. The sites were chosen by them, having regard to the extent and location of consumers' demands in their own area and to their further commitment to supply energy to the B. E. A. on the mutually agreed terms.

The sites for thermal stations, developed by the British Electricity Authority, were chosen to secure maximum economy, having regard to location of coalfields and load centres, costs of fuel transport, availability of circulating water, and costs of electrical transmission.

3.6. *Allocation of the Total kW. Capacity to individual Sites*

In arriving at the fraction of the total additional kW. capacity to be allocated to each individual site, consideration has to be given to the following four main types of station with no sharply defined demarcation between them:

(1) Hydro stations remote from load centres have allocated to them kW. capacity sufficient only to use the water normally available by running for long hours at about full load.

(2) Hydro stations near load centres have allocated to them kW. capacity sufficient to enable them to use all the water normally available for short-period operation at times of peak load.

(3) Thermal stations, either remote from or near load centres, but having cheap fuel supplies, are designed for base load operation.

(4) Thermal stations near load centres where fuel is expensive are designed for and operated for peak load supply only.

It has not yet been necessary to consider the building of thermal stations on sites remote from load centres where fuel is also expensive.

3.7. *Water and Fuel Storage*

In the case of thermal stations, stocks of coal are built up during the summer and drawn on in winter to maintain supplies to the plant despite irregularities in the flow of fuel from the pits. Stocking capacity is provided at new stations for about 25% of the annual consumption.

In the case of the hydro stations, the allied problem aries of providing reservoir capacity. Several factors determine how much should be provided. In Scotland, rainfall is well spread over the year with more in the winter than in the summer six months. In an average year, the run-off for the winter six months is about two-thirds and for the summer six months one-third of the annual average. This is illustrated in the following Table:

TABLE 3

[illegible] Distribution of Rainfall and Run-Off

	Rainfall % of annual		Run-Off % of annual	
October	10.5		11.0	
November	10.5		11.5	
December	12.5		13.5	
January	11.0		12.0	
February	9.5		10.0	
March	7.0	61.0	7.5	65.5
April	8.5		8.5	
May	4.0		3.5	
June	5.0		3.5	
July	5.5		4.0	
August	7.0		6.0	
September	9.0	39.0	9.0	34.5
		100%		100%

Annual variations in rainfall are not severe the precipitation in an exceptionally dry year being about two-thirds and in a very wet one about one and a half times the long-term average.

It is only in exceptional cases that the geological and other conditions in Scotland are favourable for the large-scale reservoirs which would be necessary to equalise annual variations. The reservoirs being constructed do, however, provide for adjustment of the seasonal variations.

The storage provided at each site has, in general, been decided by local geological conditions and, as a minimum, is sufficient to ensure that, in a dry year, water will be available so that the hydro plant will always meet its daily minimum alloted quota of kW. and kWh.

Table 4 gives values for the storage and average annual output of a selection of schemes in operation and under construction as shown in Fig. 5:

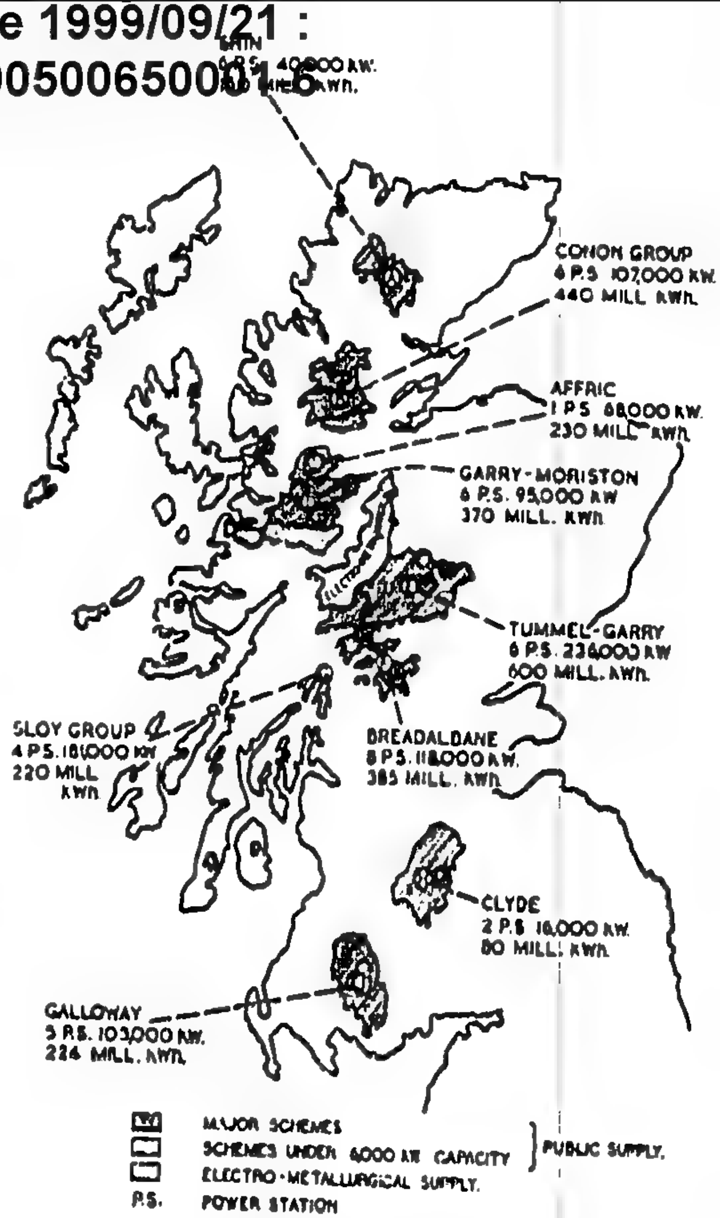

FIG. 5 - SCOTTISH HYDRO-ELECTRIC SCHEMES.

TABLE 4

[illegible] of Groups of Schemes

Name of Group	Ref. Letter on Fig. 5	Storage Capacity	Average Annual Output of Associated Stations	Storage / Output × 100
		Mill. kWh.	Mill. kWh	%
Garry-Moriston	D	200	370	54.1
Conon	B	132	440	30.0
Shin	A	57.5	150	38.3
Affric	C	75	230	32.6
Tummel	E	153	600	25.5
Breadalbane	F	87	385	22.6
Sloy	G	38	220	17.3
Galloway	J	36	224	16.1

Generally speaking, stations nearer the load centres, designed for peak or day load operation with kW. capacity relatively high in relation to the annual output, can operate satisfactorily with limited storage. With such limited storage, it is not always possible to store sudden extraordinary flows. When extraordinary flows occur at such stations, most of the additional energy available can be converted into electricity by prolonged running of the plant at full load during off-peak periods. On occasion, such so-called peak load hydro stations have been run continuously at maximum output for periods of a week to 10 days to make full use of flood water. The existence of an adequate interconnecting Grid facilitates operations of this nature. It is a simple matter, under such conditions, to shut down the less economical steam plant in order to absorb the additional kWhs. available from hydro sources.

It is an advantage to arrange in terms of seasonal variation for the maximum amount of storage for stations with kW. capacity relatively low in relation to the annual output by providing, where reservoir sites are sufficiently favourable, storage in excess of the possible seasonal deficiency. Such additional capacity may indirectly provide a reserve against unforeseen annual deficits at other schemes with limited storage.

3.8 *Special Features of North of Scotland Hydro Generation*

The positions of the catchments now in process of development are shown in Fig. 5. This area possesses mountain ranges with general elevations of 2,000 to over 3,000 feet above the sea, good rainfall with intensities varying from 150 inches in the western to 50 inches per annum in the eastern Highlands, and a temperate climate with no prolonged frosts and low evaporation losses.

[illegible] also suitable for water power development. Impervious rocks mostly underlie its river basins and provide watertight [illegible] individual catchment areas are small to that Scottish schemes are characterised by the employment of elaborate networks of collecting aqueducts and demonstrate how a small country's water power resources can be intensively and economically developed. The cost of the collecting aqueducts is balanced against the value of the extra output.

Almost all Scottish hydro schemes have to provide for the preservation of migrating fish, principally salmon. This has important effects on their selection and design. Facilities with sufficient flows of water are needed to enable salmon to ascend and descend all old as well as new obstacles to their movements and screens are required to prevent them entering the works. The amount of water set aside to ensure the movement and survival of fish life is a significant proportion of the available resources from a watershed. It may vary from 5% to 15% or even more depending on the size and importance of the river. Moreover, to maintain minimum flows in rivers, certain stations are required to run continuously.

4. COMBINED OPERATION

4.1. *General Scheme of Control*

The 132 kV. interconnecting system is run solidly connected throughout Great Britain so that all stations run in parallel.

Operation of the North of Scotland Hydro-Electric Board's stations and transmission system is controlled from Pitlochry — Fig. 2.

Operation of the British Electricity Authority's stations and transmission system is controlled from the other 7 Regional centres with an over-riding National Control in London.

Co-operation between the two Control systems is governed by the formal agreement which provides for acceptance by the B.E.A. of:

(a) Firm supplies, declared annually, in advance by the North of Scotland Hydro-Electric Board in each calendar year of a minimum number of kW. and kWh. to be taken as the British Electricity Authority may determine.
(b) Additional supplies, declared at least 3 days in advance, of kWh. which the Hydro Board may, owing to long-term favourable weather conditions, have available during the following week.
(c) Additional supplies of kWh. which the Hydro Board may suddenly have available owing to unforeseen sudden excessive rainfall.

4.2 *North of Scotland Scheme of Control*

The North of Scotland Control Engineer has, at his disposal, hydro stations and two thermal stations at Dundee and Aberdeen.

So far as the hydro stations are concerned, he makes use of all available water, having regard to the need to ensure that the levels of reservoirs are held at levels which will safeguard future demands. Heavy run-off may occur during the wet winter months November to February and even during March and April, due to melting of snow on high ground after a severe winter. During such periods, the run-of-river stations and those with limited storage are run continuously so long as the flow persists. The operation of plant with adequate storage is adjusted to ensure that reservoirs are reasonably full by the end of March in readiness for summer demands in excess of the run-off available then. At certain hydro stations it is necessary, in order to satisfy other interests, to keep variations in river flow within specified limits.

On the other hand, the North of Scotland Control Engineer is obliged:

(a) To meet the demands of consumers in Region 1.
(b) To give the firm bulk supply as declared to the B.E.A. in Region 2.

Having satisfied these two essential requirements, the Control Engineer is then left with a choice between increasing bulk supplies to the B.E.A. or restricting thermal generation at his own stations. The choice is made to secure maximum overall economy of operation for the North of Scotland Board.

4.3 *B.E.A. Scheme of Control*

The B.E.A. Controls have a somewhat different task. Their resources comprise:

(a) The supply mentioned above from the North of Scotland Hydro-Electric Board which they are obliged to accept.
(b) Certain hydro generation within the B.E.A. — mainly in Region 2, South Scotland, Fig. 2.
(c) Many thermal stations with a wide range of running costs per kWh. sent out.

They have no choice about (a). The hydro stations under (b) are run in order to use all available water subject to safeguarding future demands on reservoirs and to avoid spill. The thermal plant is run to secure maximum economy. At any given moment only those sets with

lowest running costs per unit sent out are in use. In practice, maintenance of plant, limitation of interconnecting capacity and similar restrictions cause deviations from this simple ideal.

5. INTEGRATION OF GENERATION IN 1952

5.1 *Annual Figures*

In 1952 the total output of public supply generating stations in Great Britain was 58,693 million kWh. Integration of hydro and thermal generation was largely confined to Scotland where hydro stations sent out 1,150 million kWh. or 22% of the total Scottish output. Table 5 summarises the data relating to integration in Scotland under four main headings:

(a) Energy available at sources for electricity generation.
(b) Energy required by consumers.
(c) Energy transferred.
(d) Energy generated.

For easy comparison, all quantities have been brought to a common basis and expressed as kWh. sent out from generating stations.

Fig. 6 gives the geographical background to the information in Table 5.

The North of Scotland Hydro-Electric Board Region 1 had available at hydro sources within the Region 887 million kWhs. or 16% of the total energy available in Scotland. They imported coal from South East Scotland (Region 2 (b)) to generate a further 284 million kWhs. at steam stations in Region 1 making a total generation of 1,171 million kWh.

867 million kWhs. of this total was supplied to their own consumers, and 304 exported to the B.E.A. Region 2.

The B.E.A. added this import to the energy at their disposal from sources in Region 2, namely, 4,574 million kWh. made up of 4,311 million kWh. as coal allocated to electricity generation by the National Coal Board, and 263 million kWh. obtained from hydro sources in the South West. The coal was used to generate 3,740 million kWh. in Region 2 — mostly in the South West — the balance being sent mainly by sea to English generating stations. The consumers in Region 2 took 3,037 kWh. in the South West Region 2 (a) and 1,258 kWh. in the South East Region 2(b).

In very general terms there was, as can be easily seen from Fig. 6, a triangular situation with heavy consumption in the South West, ample coal supplies in the South East, and three-quarters of the hydro supplies in the North.

TABLE 5

Integration of Electricity Generation in Scotland in 1952

Energy (For Electricity Generation) (All Figures In Million kWh.)

	Required By Consumers (Including Losses)	Transfers								Sent Out From Generating Stations		
		As Coal				Electrically		Total				
		By Sea		By Rail								
		Export	Import	Export	Import	Export	Import	Export	Import	Thermal	Hydro	Total
	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
	867	—	—	—	284	304	—	20	—	284	887	1,171
	3,037	—	—	—	1,870	180	—	—	1,690	2,954	263	3,217
	1,258	314	—	2,154	27	--	472	1,969	—	786	—	786
	5,162	314	—	2,154	2,181	484	472	1,969	1,690	4,024	1,150	5,174
...ports or Imports		314			27	12		299				

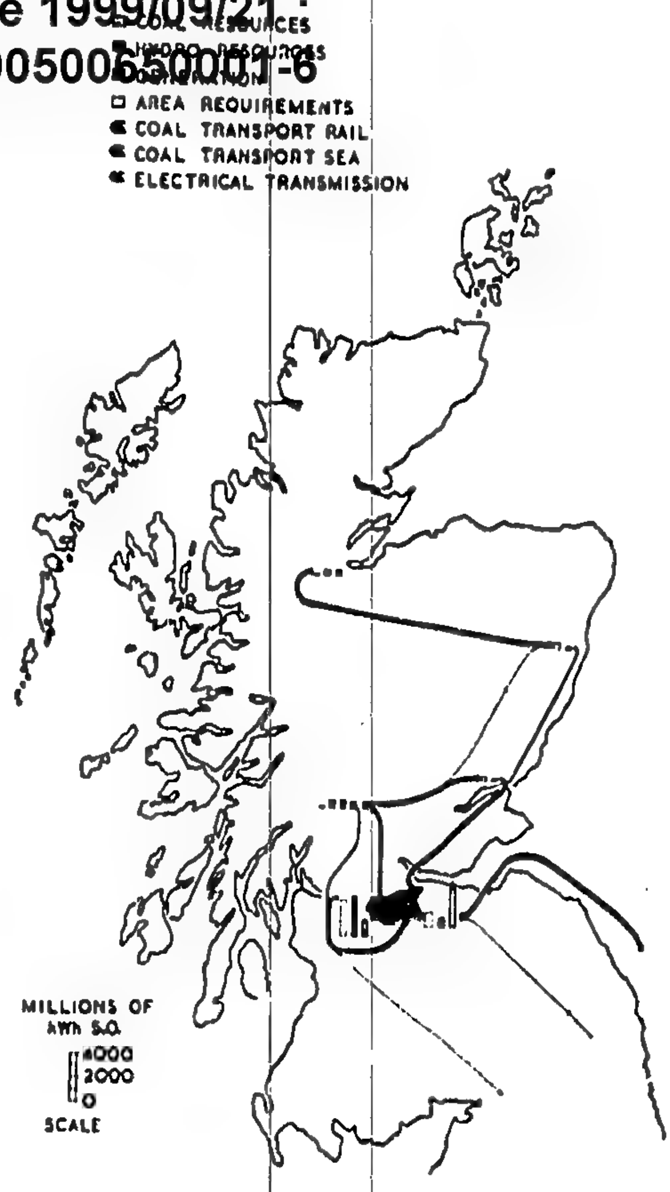

FIG. 6 - ENERGY FLOWS - SCOTLAND. 1952.

The installed capacities of the hydro and thermal stations in Scotland at 31st December, 1952, are set out in Table 6·

TABLE 6

Installed Capacity of Generating Plant in Scotland at 31st December, 1952

REGION		Installed Capacity (All figures in MW.)		
	No.	Thermal	Hydro	Total
N. Scotland	1	168	391	559
S. W. Scotland	2(a)	741	119	860
S. E. Scotland	2(b)	249	—	249
Scotland	1 and 2	1,158	510	1,668

5.2. *Scottish Daily Generation Programmes 1952*

5.2.1. *North of Scotland Arrangements*

The aims of the North of Scotland Control have already been described in general terms in Section 4.2.

In 1952, so far as the hydro stations are concerned, a provisional programme was made up each Thursday detailing the output for each hydro group of stations for the following week-end and for Monday to Friday inclusive of the following week, having regard to the storage conditions at the time, the run-off into the different catchments, the contribution from the supporting thermal stations, any proposed outages of transmission lines for maintenance, and the kilowatt available capacity at each generating station. This programme also had regard to the previously agreed daily contribution to the B.E.A. in South Scotland.

Such a programme was conditional on no unforeseen variation in weather conditions. When heavy rainfall occurred over the week-end, radical adjustments were necessary.

During 1952, for example, 50 million kWh. were, owing to unexpected rain, exported to the B.E.A. in South Scotland on a short notice basis over and above the firm delivery declared in advance at the beginning of the year.

The supplies of fuel to and outputs of the thermal stations were planned to provide the total output required to make up regional consumers' requirements and agreed export to the South.

The [illegible] hydro generation was next spread over the groups of stations mostly on the same watershed. Each group was given [illegible] the peak kW. demand during the day and the average kW. required during morning, afternoon, evening, and nigth.

Within each group the programme was further broken down, according to the conditions ruling, in order to obtain as far as practicable the most economic output from the machines on load. Small variations in output were met by selected hydro stations with the flattest efficiency curves. Fluctuations in the load on the thermal plant were avoided as far as possible.

5.2.2. *South Scotland Daily Arrangements*

The South Scotland Control at Glasgow had a different task. They had to conform to general directions from National Control in London. The aim of these directions was to generate the B.E.A. national requirements at minimum cost. Each of the Regions 2 to 8 was instructed to provide for the common pool a given output, hour by hour, from its own generating resources. The Glasgow Control Engineers had at their disposal .

(a) The above-mentioned supply from Region 1.
(b) Hydro resources in South-West Scotland (Galloway Scheme).
(c) A number of thermal stations of varying sizes with widely differing incremental costs per kWh. sent out.

The period during which the daily kWh. from Region 1 was to be used was agreed after discussion between the two Controls of Regions 1 and 2. Since the national kW. capacity was hardly sufficient to meet the national load full advantage had to be taken of the supply during peak hours.

Similarly full use had to be made during peak hours of the supply available from the hydro resources in South West Scotland.

The balance of the total contribution to the national output required from Glasgow Control was obtained from the thermal plant in the region. The individual units of generating plant were arranged in "order of merit", depending on the running costs in pence per kWh. sent out. At any given moment, only those units with the lowest running costs were in use, subject, of course to availability of generating and transmission plant and capacity of interconnecting circuits.

5.3. *Peak Load Conditions*

It is difficult to give a brief description of the changes made from hour to hour by the various Controls. The national peak load occurred between 16.30 and 17.00 hours on Tuesday, 30th December, 1952.

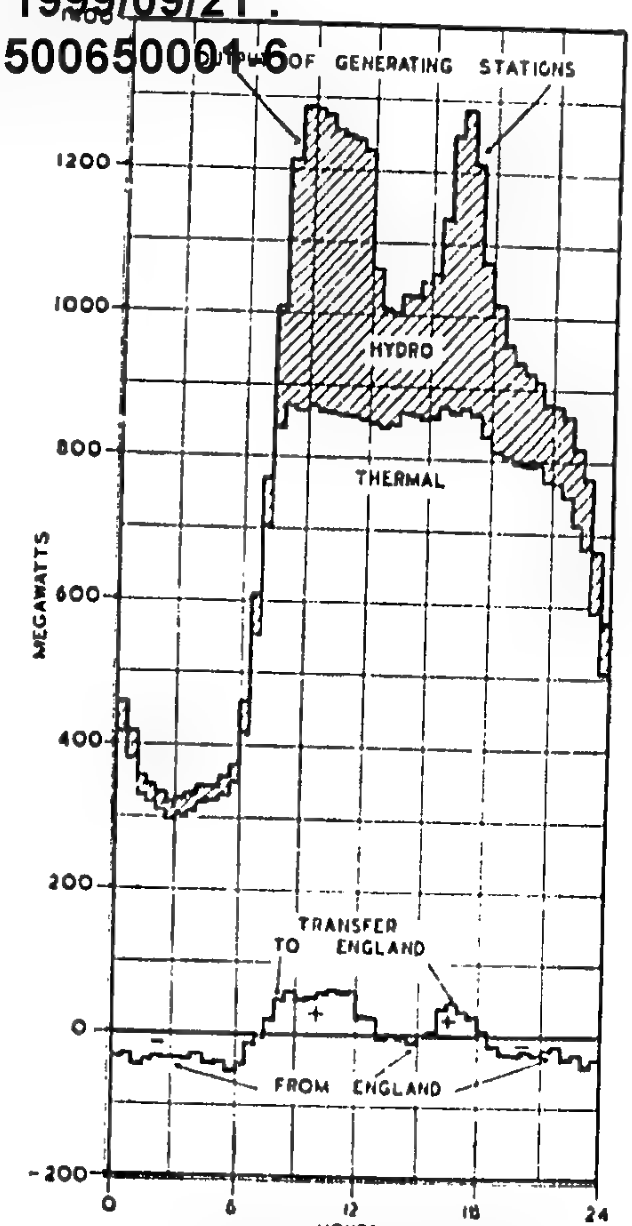

FIG. 7-LOAD CURVE FOR SCOTLAND TUESDAY 30TH DEC. 1952.

Fig. 7 shows the variations throughout the day in generation in [illegible] and from England.

Fig. 6 indicates the individual flows over the main 132 kV. circuits in Scotland at the peak half-hour. It will be seen that the group of hydro stations to the North and adjacent to the load centres in the South were supplying a total of 182 MW. over three lines. 137 MW. of this was absorbed in South Scotland with the result that, in turn, this region sent South 45 MW. into England to help to meet the deficiency there.

Table 7 gives the distribution of generation and load throughout Great Britain during this half-hour.

6. FUTURE DEVELOPMENTS

In common with that of all countries, the public demand for electrical energy in Great Britain is increasing rapidly. Between 1947 and 1952 the kWh. sold increased by 47%. For Scotland alone the increase was 52%. It is expected to increase steadily over the whole country for many years to come. The production of additional energy is therefore a continuing problem.

Plans for the development of all the thermal stations in Great Britain are based on the National Coal Board's plans for allocation of the coal required for electricity supply from the individual coalfields. Referring to Table 5, the immediate major change in Scotland so far as thermal development is concerned will be a considerable increase in the proportion of coal obtained in South East Scotland and the provision of additional thermal plant in that region.

The corresponding development of hydro resources must take place in North Scotland where, as already indicated in Table 1, plans have been made for a production of about 3500 million kWh., probably available in the early 1960's.

A survey made in 1944 showed that this annual output might be economically developed to 6,450 million kWh. More recent investigations point to a potential output of about 10 000 million kWh.

In the early 1960's, if these estimates are realised, the position in Scotland is expected, following the form of presentation used in Table 6, to be very roughly as follows:

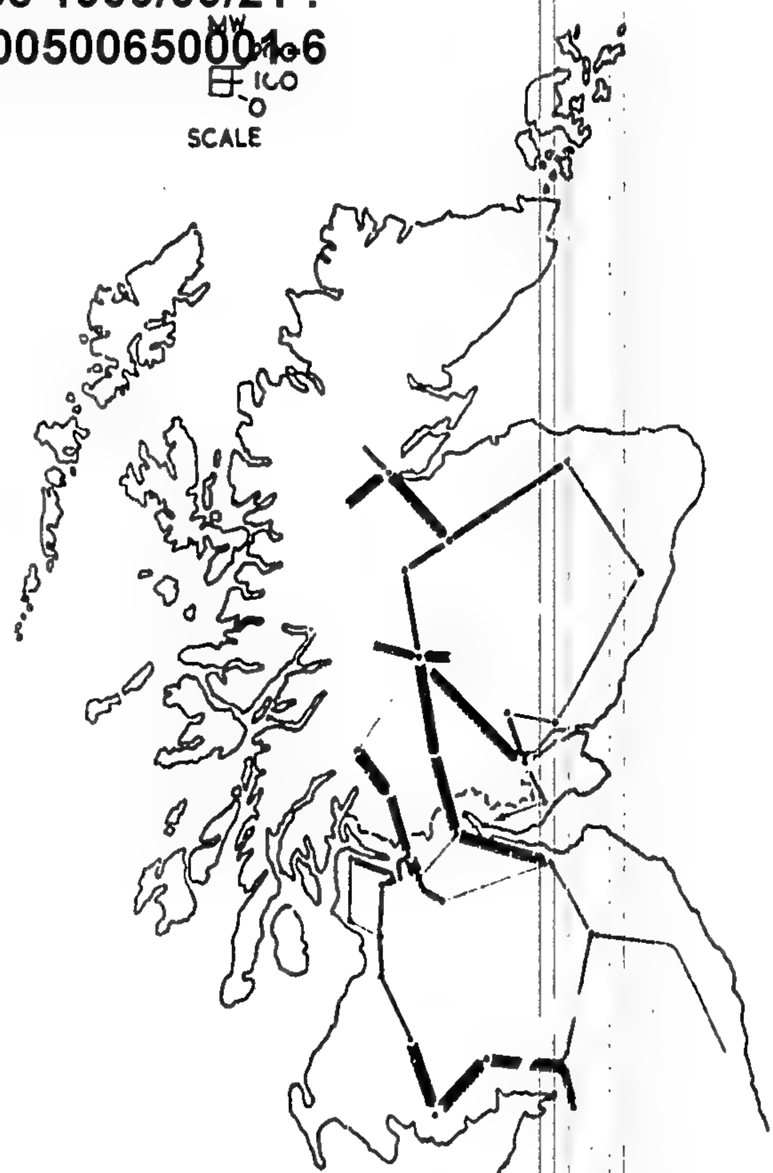

FIG. 8 - MW FLOW AT WINTER PEAK 1952

TABLE 7

Distribution of generation and load at time of national Peak load

1 30 — 17 00 hrs. Tuesday, 30th December, 1952

REGION Name	No. on Fig. 2	Generation MW. s.o.	Consumers' Load Incl. Losses MW. s.o.	Export MW. s. o.	Import MW. s. o.
(1)	(2)	(3)	(4)	(5)	(6)
North Scotland	1	424	242	182	—
South Scotland	2	864	1,001	—	137
North East England	3	660	661	—	1
North West England	4	2,337	2,329	8	—
Mid-East England	5	1,584	1,537	47	—
Central England	6	2,328	2,308	20	—
South East & East England	7	3,959	3 961	—	2
South West England	8	1,633	1,750	—	117
Great Britain		13,798	13,789	257	257

TABLE 8

Integration of Electricity Generation in Scotland

Possible Pattern in early 1960's

(All figures in million kWh. annum)

Region No.	North 1	South-West 2(a)	South-East 2(b)	Total
A. Energy available at Sources				
Coal (for electrical generation)	—	1,700	7,300	9,000
Hydro	3,200	300	—	3,500
Total	3,200	2,000	7,300	12,500
B. Energy required by Consumers	2,000	4,500	2,500	9,000
C. Energy transferred				
1. Coal Export (by se to England	—	—	3,500	3,500
2. Coal by Rail Export	—	—	1,000	0
Import	400	600	—	
3. Electrical Export	1,600	—	300	
Import	—	1,900	—	0
D. Energy generated in Scotland				
At Thermal Stations	400	2,300	2,800	5,500
At Hydro Stations	3,200	300	—	3,500
Total	3,600	2,600	2,800	9,000

7. PUMPED STORAGE

The integration of thermal with hydro generation in Great Britain does not at present include an associated system of pumped storage. However attractive from an operating point of view, such schemes must also be justified on economic grounds. The geographical conditions and

[illegible] is favourable in Great Britain as in other countries. A number of prospective schemes are again being studied and [illegible] more may prove to be suitable for development under present-day conditions.

8. TIDAL POWER

The tides as a source of energy have been the subject of careful study in Great Britain. Attention has been focussed on the Severn estuary at the western sea end of wich there is a tidal range varying between 47.6 feet at spring tide to 22.2 feet at neap tide.

A scheme has been worked out in detail for single basin single tide working to give an annual output at the turbines of about 2 300 million kWh. per annum.

The scheme provides for direct connection of the generators to the Grid and for addition of their output to the national pool, and for shutting down the thermal plant with highest running costs during the hours the tidal energy is available. The kW. output of the Severn tidal station would vary between:

800 MW. 2 2/3 million kWhs. per spring tide
and 300 MW. 1 1/3 million kWhs. per neap tide

The main result of operation would be to save coal at the rate of about one million tons per annum. The possible saving will decrease as thermal stations become more efficient.

Under present conditions the extra annual charges — mostly capital charges on the works required — are somewhat greater than the annual cost of the coal saved, but the difference is not great and, if coal costs continued to rise after the scheme were built the balance would change in favour of the scheme. Development of reversible working might also change the balance. The scheme would provide an excellent means of employing national resources of labour during a trade recession.

9. 275 kV. GRID

Mention has already been made of the function of the 132 kV. Grid in integration of generation in Great Britain. A 275 kV. Grid is now under construction, as shown in fig. 4. The connection to the Clyde estuary load centre in Scotland will be noted.

It will also make easier the acceptance by the general pool of the output of the Severn Tidal Scheme should it be constructed. The spur to South Wales will cross the Severn Estuary in the neighbourhood of the proposed Barrage, and it will be possible to connect the tidal generating station directly to the 275 kV. lines. The tidal energy can then spill over the 275 kV. network and be absorbed at the heavy load centres in the

... [illegible] The thermal plant with the highest incremental running cost per KWh. will be shut down, while the tidal energy is [illegible]

The load in the southern part of England is already over 3.000 MW during a summer evening. There will, therefore, be little difficulty in accepting the tidal energy even during night hours.

10. INTERCONNECTION WITH FRANCE

The proposal to interconnect the supply systems of the B.E.A. and Electricite de France by a submarine cable between Dover and Calais has been studied by both Authorities and work is now preceding on the development of the scheme. If this link should be established, another step will have been taken in the integration of hydro and thermal generation. It will be possible to make better use of the combined hydro and thermal resources of both countries to their mutual advantage.

11. CONCLUSION

The Authors hope that this brief account of the integration of hydro and thermal power in Great Britain may be of interest to their fellow Engineers in countries where conditions are somewhat similar.

SUMMARY

Integration of hydro and thermal generation in Great Britain is significant in Scotland where the water power resources of North Scotland are utilised in conjunction with the coal resources of South Scotland.

The 132 kV Grid is an essential factor in the development, which has been accelerated by the North of Scotland Hydro-Electric Board set up in 1943

Scottish hydro schemes at present in various stages of development have a total capacity of 1.215.600 kW. and an average annual output of over 3.500 million kWhs per annum.

In Great Britain, additional generating capacity is added annually, following a programme designed to provide nationally the bare minimum of capacity required to meet the winter peak load. The North of Scotland Board provide additional hydro capacity, having regard to financial and other considerations. The balance is provided as thermal plant by the British Electricity Authority The additional capacity is allocated to suitable sites according to their distances from the load centres and in the case of thermal stations, the cost of fuel.

Fuel storage up to 25% of the annual consumption is provided at thermal stations, while reservoir capacity is provided for hydro schemes to deal with seasonal changes in the relation between run-off and demand.

All generating stations are connected to the 132 kV. Grid system and are controlled from one National and eight Regional Control Centres.

Conditions in Scotland during 1952 are described. Hydro stations supplied 22% of the Scottish output in that year, and, at the end of the year, had 510 MW. of plant out of the total of 1 668 MW. at all Scottish stations.

As an example of day-to-day operation, details are given of the conditions on Tuesday, 30th December, 1952, the day of the British national peak load.

Brief reference is made to the possible pattern of generation in Scotland in the early 1960's, when hydro stations are expected to supply 3,500 million kWhs. per annum or 30% of the total Scottish output. Recent investigations point to a potential hydro output of about 10,000 million kWhs. per annum.

Pumped storage has not been developed in Great Britain but some projects are again under examination.

The Severn Tidal Power Scheme is expected to save about 1 million tons of coal annually and could easily, when economic conditions become more favourable, be integrated with the remainder of the country's resources.

Work is in progress in connection with the development of a scheme to interconnect the French and British systems by a submarine cable between Dover and Calais.

Résumé

L'intégration de la production hydraulique et de la production thermique a une importance particulière en Ecosse où les ressources hydrauliques de l'Ecosse septentrionale sont utilisées conjointement avec les ressources de charbon de l'Ecosse méridionale.

Le réseau de transmission à 132 kV représente un facteur essentiel dans le développement général, qui a été acceleré par le North of Scotland Hydro-Electric Board créé en 1943.

Les projets hydrauliques ecossais qui, à present, ont atteint divers stades d'exécution, représentent une capacité totale de 1215,6 MW et une production annuelle moyenne depassant 3,500 GWh.

En Grande Bretagne, de nouveaux moyens de production sont ajoutés tous les ans suivant un programme d'equipement prévu de façon à pourvoir, à l'échelle nationale, le minimum essentiel pour faire face à la pointe d'hiver. Le North of Scotland Board fournit de nouveaux moyens de production hydraulique ayant regard à certaines considérations financieres et autres. Le reste est fourni par des installations thermiques de la British Electricity Authority. Les nouveaux moyens de production sont

[illegible] emplacements choisis suivant leur distance des centres de consommation et dans le cas des centrales thermiques, suivant le coût [illegible].

Une réserve de combustible allant jusqu'a 25% de la consommation annuelle est prévue dans les centrales thermiques, alors que la capacité de réserve hydraulique es telle qu'elle puisse pourvoir aux variations saisonières de la relation entre le fil de l'eau et la demande.

Toutes les centrales sont reliées au reseau à 132 kV et fonctionnent en parallèle. Elles sont controllées par un Centre National et huit Centres Régionaux de répartition.

La situation en Ecosse pendant l'année 1952 est décrite. Au cours de cette année les centrales hydrauliques ont fourni 22% de la production totale de l'Ecosse et, à la fin de l'année, leur puissance était de 510 MW alors que la puissance totale des centrales écossaises était de 1.668 MW.

Pour donner un exemple de l'exploitation journalière, des détails sur la situation pendant la journée du 30 Décembre sont fournis, date de la pointe nationale en Grande Bretagne.

Une brève allusion est faire sur l'évolution éventuelle de la production en Ecosse vers les 1960 quand la production prévue des centrales hydrauliques sera de 3.500 GWh par an où 39% de la production totale de l'Ecosse. Des études récentes indiquent que la production hydraulique annuelle possible est de l'ordre de 10.000 GWh.

Les installations de pompage n'ont pas encore été développées en Grande Bretagne mais certains projets sont de nouveau a l'étude.

Le projet de l'installation marémotrice de la Severn pourrait économiser environ 1 million de tonnes de charbon par an et pourrait facilement, quand les conditions économiques deviendront plus favorables, être intégré avec les autres ressources du pays.

Des travaux sont en cours ayant rapport à l'étude d'un projet pour interconnecter les réseaux français et anglais au moyen d'un câble sousmarin entre Douvres et Calais.

Resumo

A integração da energia termica e hidro-eletrica na Grã-Bretanha tem significado especial na Escócia onde aos recursos hidraulicos do norte se associam os recursos carboniferos do sul.

A rêde de 132 kV. é um fator essencial no desenvolvimento que tem sido acelerado pela "North of Scotland Hydro-Electric Board" (Junta Hidro-Elétrica do Norte da Escócia) estabelecida em 1943.

Os projetos hidro-eletricos escoceses presentemente em várias fases de desenvolvimento, tem uma capacidade total de 1.215.600 kW, e uma produção média anual superior a 3.500 milhões de kW.-hora por ano.

Na Grã-Bretanha aumenta-se anualmente a capacidade de produção de energia segundo um programa que tem por finalidade o alcance da capacidade nacional mínima necessária para satisfazer a carga máxima de inverno.

A "North of Scotland Board" fornece capacidade hidro-elétrica adicional conforme as possibilidades financeiras e outras considerações. O balanço é preenchido com instalações térmicas pela "British Electricity Authority"". A capacidade adicional é alocada a sítios convenientes segundo as distâncias a que se encontram dos centros de carga e custo do combustível no caso de centrais térmicas.

As centrais térmicas têm condições para armazenar até 25% do combustível consumido anualmente e as instalações hidro-elétricas possuem reservatórios apropriados às variações devidas às estações do ano na relação entre a descarga (run off) e as necessidades (demand).

Tôdas as centrais geradoras estão ligadas à rêde de 132 kV. e funcionam em paralelo. As centrais são controladas por centro nacional e oito centros regionais de comando.

Descrevem-se as condições na Escócia durante 1952. As centrais hidro-elétricas forneceram 22% da produção total escocesa dêsse ano e no fim do ano tinham instalações no montante de 510 MW., quando o total de tôdas as centrais escocesas era de 1.668 MW.

Para exemplificar a rotina diária dão-se detalhes das condições na têrça-feira, 30 de dezembro de 1952, dia em que a carga nacional britânica atingiu o máximo.

Faz-se uma breve referência ao possível arranjo da produção de energia na Escócia em princípios da década 1960-70, altura em que as centrais hidro-elétricas deverão contribuir com 3.500 milhões de kW.-hora por ano, ou 39% da produção total escocesa. Investigações recentes indicam uma produção potencial de energia hidráulica de cêrca de 10.000 milhões de kW.-hora por ano.

Armazenamento bombeado não tem tido desenvolvimento na Grã-Bretanha, mas alguns projetos estão novamente a ser estudados. Espera-se que o "SEVERN TIDAL POWER SCHEME" (plano para aproveitamento da energia das marés no Severn) poupe um milhão de toneladas de carvão anualmente, e quando as condições econômicas se tornarem mais favoráveis, poderá fàcilmente ser integrado aos restantes recursos do país.

Presentemente, trabalha-se na elaboração de um projeto para interligar as rêdes francêsa e inglesa por meio de cabo submarino entre Dover e Calais.

CONFERÊNCIA MUNDIAL DA ENERGIA
WORLD POWER CONFERENCE

TITULO 2
Assunto 2-1-1

REUNIÃO PARCIAL
SECTIONAL MEETING
Rio de Janeiro - 1954

FERRAZ (O.M.)
Brasil

L'USINE HYDRO ELECTRIQUE DE PAULO AFONSO SUR LE SÃO FRANCISCO DE LA "COMPANHIA HIDRO ELÉTRICA DO SÃO FRANCISCO"

Par OCTAVIO MARCONDES FERRAZ

COMITE NATIONAL BRASILIEN

INTRODUCTION

Au Nord du Brésil et plus particulièrement dans le Nord-Est il existe une vaste région d'une surface de 511.000 km² qui est contenue dans un cercle dont le centre est Paulo Afonso et dont le rayon a 450 km. Cette région est constituée en grande partie par des terrains situés dans ce que l'on appelle le "Poligono das Sêcas" et n'a pratiquement pas, jusqu'à présent, des sources pondérables d'énergie hydrauliques aménagées.

Cette région est comprise entre les parallèles 5°17' et 13°31' S et son climat malgré sa latitude voisine de l'Equateur, n'a rien de comparable aux régions africaines correspondantes. Elle pourra se développer moyennant l'exécution d'un vaste programme ayant pour base: *transports et énergie*. Cependant, toujours de Paulo Afonso comme centre et dans un rayon de 50 km environ il est possible d'équiper une puissance presque égale à la puissance totale équipée au Brésil jusqu'à ce jour. Il a été décidé d'aménager Paulo Afonso. Cet aménagement s'imposait pour économiser les devises (importation de combustibles) et pour épargner nos forêts (bois à brûler).

Etant donné l'immensité de cette surface et la distribution très irrégulière de la population et des activités diverses, la grande région tributaire de l'énergie de Paulo Afonso ne pourra pas jouir de ses avantages car il ne serait pas économique de la transporter à d'aussi grandes distances et en quantités encore restreintes (Fig. 1). L'énergie sera tout d'abord transportée vers des zones plus développées de façon à garantir la stabilité économique de l'entreprise.

La "Companhia Hidro Elétrica do São Francisco" (CHESF) concessionnaire [illegible] ce que nous appellerons la "*grande pente du São Francisco*" a été chargée d'en étudier et équiper les ressources. Trois solutions se présentèrent:

- Utilisation de la chute d'Itaparica
- Utilisation de la chute de Paulo Afonso
- Utilisation de la différence de niveau le long du Cañon

Après sélection, la CHESF a choisi Paulo Afonso pour démarrer son programme.

LOCAL ET OBJET

L'Usine Hydro Electrique de Paulo Afonso est située sur le S. Francisco entre les Etats de Bahia et Alagôas. Ses coordonnés géographiques sont: 38° 12' de longitude Ouest et 9° 21' de latitude Sud. En ligne droite

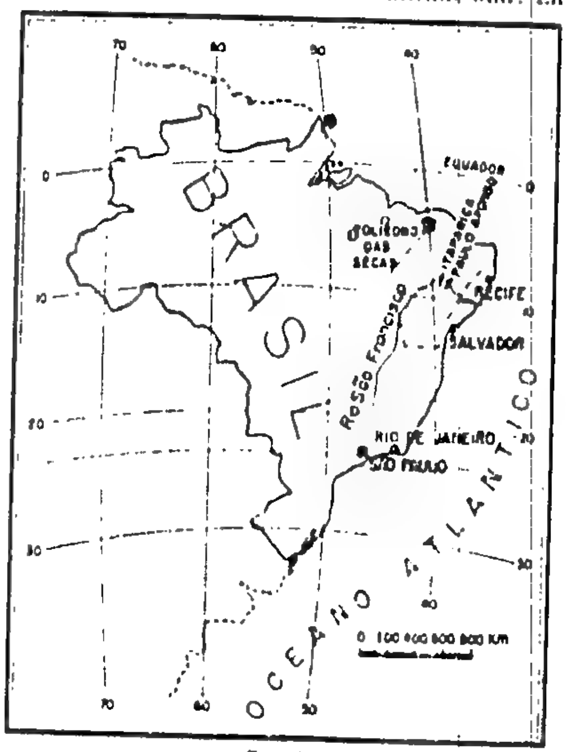

Fig. 1

elle se trouve à 390 km de Récife, 265 km de Maceio, 210 km de Aracaju, 400 km de Salvador et 255 km de Joazeiro (Bahia). Le but de la CHESF était donc d'utiliser une différence de niveau qui varie entre 75 et 92 m au cours de l'année (considérant une période de 20 ans).

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L'énergie ainsi obtenue sera transmise par deux lignes principales aux deux centres plus importants de consommation: Récife et Salvador.

Sur ces deux lignes seront installées les sous-stations d'où la transmission va s'irradier vers les points d'utilisation, atteignant des localités de plus en plus lointaines, diffusant et vulgarisant ainsi l'usage du courant. Il est évident que cette vulgarisation, même pour une Compagnie du gouvernement comme la CHESF, doit obéir à un schéma technico-économique qui a été l'objet, et l'est encore, d'études de la part de sa Direction.

DESCRIPTION

Les cataractes de Paulo Afonso sont situées sur un plateau dont l'altitude moyenne à proximité des chutes est de 255 m au-dessus du niveau de la mer avec une légère pente vers l'Est.

Le fleuve sillonne ce plateau suivant une direction Nord-Ouest-Nord-Est et fait, à l'endroit des chutes, un coude à 90°; les eaux tombent dans une grande *brèche* ouverte dans le même plateau qui maintient son altitude. En amont des chutes le fleuve s'écoule, tranquille jusqu'à leur voisinage (environ 6 km en amont) et ensuite se précipite dans le fond du cañon étroit et profond qui formera son lit sur environ 10 km; l'altitude

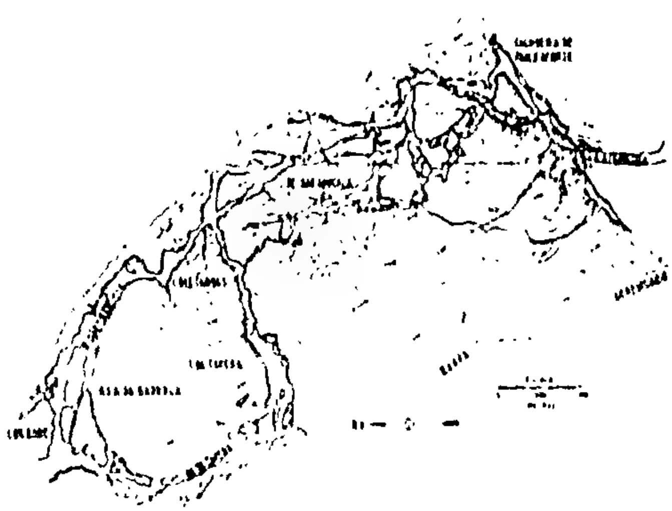

Fig. 2 — Rio São Francisco à Paulo Afonso — Tracé des barrages

du plateau tombe alors brusquement, le lit s'élargit et le fleuve redevient une surface de 607 000 km². Le, 5 à 6 km du fleuve immédiatement en

amont des chutes de Paulo Afonso ont une pente très supérieure à la [illegible] un système enchevêtré de chenaux ou "bras" qui pratiquement se rejoignent au sommet des chutes (fig. 2).

Le projet qui est en exécution actuellemente à Paulo Afonso et touche sa fin, comprend essentiellement deux barrages, un insubmersible (Barrage Ouest) ayant une longueur de 1.146,99 mètres et un autre (Barrage Est) ayant une longueur de 3.056,70 mètres dont 2.583,21 mètres en déversoir, 273 en barrages mobiles (vannes planes) et 197,76 en barrage insubmersible. Ces barrages ont une hauteur moyenne de 10 mètres et un volume total de béton de 240.000 m³. Ils répondent à un triple but: barrer le fleuve, former un bassin de décantation d'environ 8,5 km² et finalement constituer l'ouvrage d'adduction menant les eaux jusqu'à la prise d'eau ou chambre de mise en charge proprement dite. En ce point

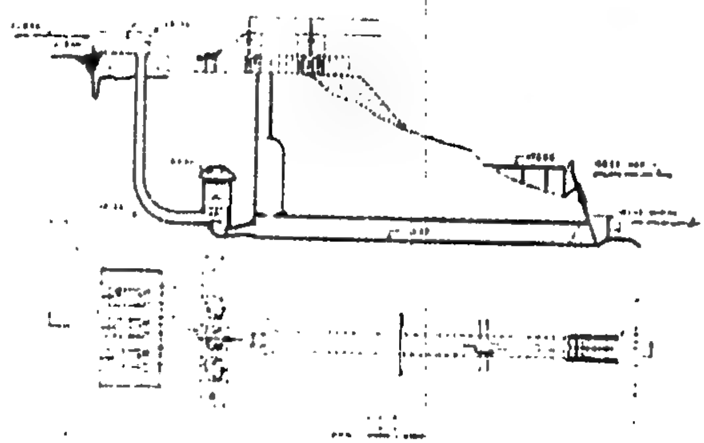

Fig. 3 — PAULO AFONSO — Plan et Coupe Longitudinale de l'aménagement

les eaux pénètrent dans trois puits (n.º 1 A, 1 B et 1 C) de 1,80 m de diamètre et 100 m de long chacun, pour alimenter (fig. 3) trois turbines Francis de 83.000 HP à arbre vertical projetées pour fonctionner sous une chute brute de 83,5 m et nette de 81 m (266 pieds), tournant à 290 tour p.m. Les eaux sont restituées au São Francisco par un tunnel de 180 m de long et de 10 m de diamètre. A la sortie des aspirateurs il a été aménagé une cheminée d'équilibre (puits n.º 3) ayant 14 m de diamètre à la base et communicant avec l'air extérieur par un puits cylindrique de 6,50 m.

Les turbines qui sont directement accouplées avec des alternateurs de 60.000 KW, 13.800 Volts, 60 périodes, forment des groupes électrogènes logés dans une salle souterraine ayant les dimensions brutes (dimensions des excavations) suivantes: 17 m de large, 61 m de long et 33 m de haut. En plus des trois puits adducteurs et de la cheminée d'equilibre décrits ci-dessus, deux autres puits ont été forés: le puits n.º 2 d'un dia-

mètre de 6,5 m qui permet l'introduction des grosses pièces dans la salle [illegible] est logé l'ascenseur d'accès et les barres omnibus. Entre ces deux puits qui débouchent à la surface respectivement dans le hall de montage des transformateurs et dans le bâtiment de contrôle, est située, à l'air libre, la sous-station élévatrice où la tension est transformée de 13.800 à 22.000 Volts, tension à laquelle est fait le transport de l'énergie vers Récife et Salvador.

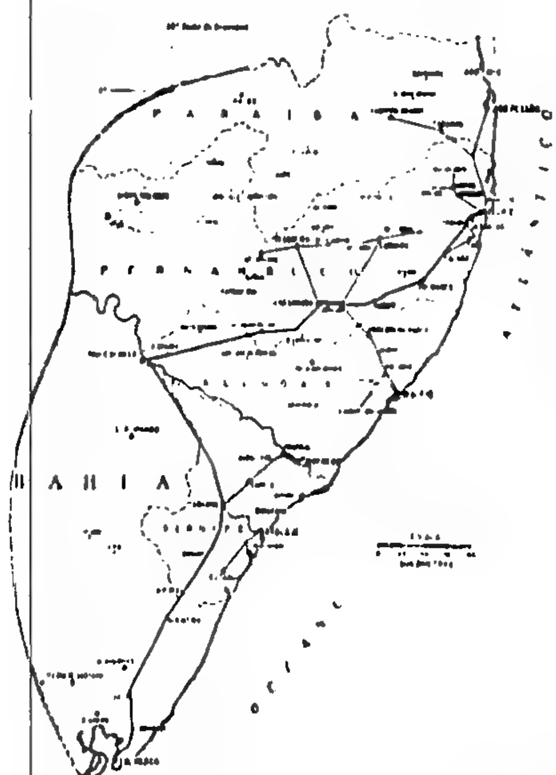

Fig. 4 — PAULO AFONSO — Le système de transmission

Ces lignes de transmission ont respectivement 105 km dans la direction de Récife et 165 km dans la direction de Salvador (fig. 4). Aux extrémités, dans les sous-stations sont placés des moteurs synchrones ou des condensateurs synchrones qui permettent le réglage de la tension. Les lignes à 220.000 Volts sont portées par des pylônes en acier galvanisé (en moyenne 2,5 pylônes par km). Les conducteurs sont en aluminium avec âme d'acier et ont une section de 736.000 C M. Ils sont montés sur des chaînes d'isolateurs de 16 disques dans les alignements droits. Les fils de terre sont constitués par des câbles d'acier galvanisé de 3/8". Le contrepoids est constitué par des fils "copperweld"

ETUDES ET PROJETS

Les études, projets et details ont été réalisés par les bureaux techniques de la CHESF, y compris les travaux de prospection hydrométriques, géologiques et topographiques. Nous avons cependant consulté divers spécialistes et entités comme l' Instituto de Pesquisas Tecnologicas de São Paulo" et autres. Nous avons reçu un grand nombre de données hydrometriques de la "Divisão de Aguas do Ministerio da Agricultura" et avons fait des études sur *les tables a calcul* de la São Paulo Light & Power Co et à la Westinghouse à East Pittsburgh (Pa).

CHUTE

En considerant la courbe des différences de niveaux classees (moyenne de 20 ans) on a conclu que la solution la plus avantageuse etait celle qui correspondait a une chute ou difference de niveau qui se verifie pendant 65% de l'annee: 83,50 m, tout en specifiant au constructeur des turbines qu'il devait garantir un rendement encore eleve pour des chutes 7,2% en-dessous de la normale. Cette derniere chute (77,5 m) se verifie pendant 90% de l'annee. Avec la chute adoptee comme normale (83,5 m) la production de l'usine (complètement équipee) sera de 5.721 millions de KWH en tablant sur un facteur de charge de 0.7. Si l'on avait adopté la chute minimum (durée 100% *pour l'annee moyenne*) soit 75 m, la production ne serait plus que 5 232 millions de KWH. Au prix de vente moyen de Cr$ 0,25 (cruzeiros) par KWH la solution adoptée (celle qui est en execution) conduit à une augmentation de la recette de Cr$ 122 250 000 (cruzeiros) par an quand toute l'usine sera équipee

DEBITS

Le debit de 799 m³ sec — 800 en chiffre ronds — ne s'est verifie a Paulo Afonso que durant 81 jours (repartis sur 3 ans) sur une periode de 20 ans, soit 7 300 jours. C'est ce débit de 800 m³ sec que nous avons adopte pour le fonctionnement au fil de l'eau. Cette valeur tient compte des pertes par evaporation et infiltration qui se produisent entre le poste d'observation et les chutes. Ces pertes sont de 0,202 m³ sec par kilometre de fleuve. Le debit ci-dessus permet d'obtenir 550.000 KW sans regularisation. Régularisant le debit a 1 300 m³ sec on pourra équiper 900 000 KW — puissance pour laquelle ont éte faites nos etudes. Cette regularisation sera presque automatique, a mesure que s'installeront des usines sur le haut S. Francisco et ses affluents qui, comme on le sait, arrosent une zone riche et en franc progres

BARRAGE

Le trace du barrage repond a trois objectifs: barrer le fleuve, épurer les eaux et les diriger. Les profils longitudinaux des deux chenaux les

plus importants, montrent qu'il est nécessaire de construire un barrage [illegible] alimenter l'usine durant l'étiage si la prise d'eau se trouvait sur le bras secondaire: celui-ci a un profil plus élevé et sèche complètement quand l'étiage est particulièrement prononcé (fig. 5). Le choix définitif du tracé a été effectué considérant que l'on devait réduire le plus possible le volume de béton et les difficultés de construction. Le barrage est en partie fixe, en partie mobile. Le type barrage-poids s'est trouvé être le plus économique pour la partie fixe, étant donné

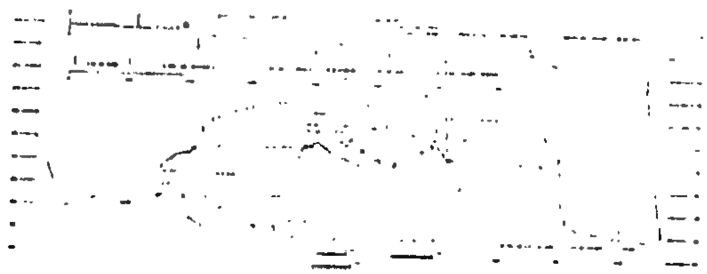

Fig. 5 — PAULO AFONSO — Profil en long du fleuve à l'endroit des chutes

la grande irrégularité du profil du terrain. Placé plus en amont il s'allongerait inutilement et plus en aval il devrait traverser un lit excessivement profond. La côte de sa crête fut choisie en considérant qu'elle donnerait la plus grande différence de niveau pour l'aménagement, sans courir le risque d'avoir à contenir des débordements intempestifs en amont — ce qui porterait atteinte à l'économie de la solution. Le barrage est prévu pour l'utilisation totale de 900.000 KW.

ÉVACUATION DES CRUES

Pour évacuer les crues, ont été prévues 26 vannes planes à deux panneaux, divisées en 4 groupes, chacun équipé d'un pont roulant. Elles constituent la partie mobile du barrage. Leur superficie totale est de 2.400 m² leur capacité totale d'évacuation est de 10.000 m³/sec. En outre, les crues sont évacuées par un déversoir de 2.583,21 m de long qui, pour une lame de 1,50 m, a un débit de 10 000 m³/sec. La plus grande crue — d'ailleurs catastrophique — se produisit en 1926, son débit atteignant 16.740 m³/sec.

La construction des piliers et des radiers de la partie mobile a présenté de grandes difficultés dans la traversée du Bras Principal du fleuve. Il a été fait appel à un procédé original permettant la construction du batardeau; ce procédé sera l'objet d'une communication à part dans cette section-ci de la Conférence Mondiale de l'Energie.

PRISE D'EAU

La prise d'eau a été étudiée de façon à faciliter l'exécution des étapes futures, qui seront construites à mesure qu'augmentera la demande exigée par le marché à approvisionner (fig. 6).

Pour chaque unité il a été prévu une conduite indépendante. A l'entrée, une grille et une vanne secteur de 9 x 10,50 mètres constituent tout l'appareillage de contrôle de la conduite. Toutes les extensions seront construites à sec.

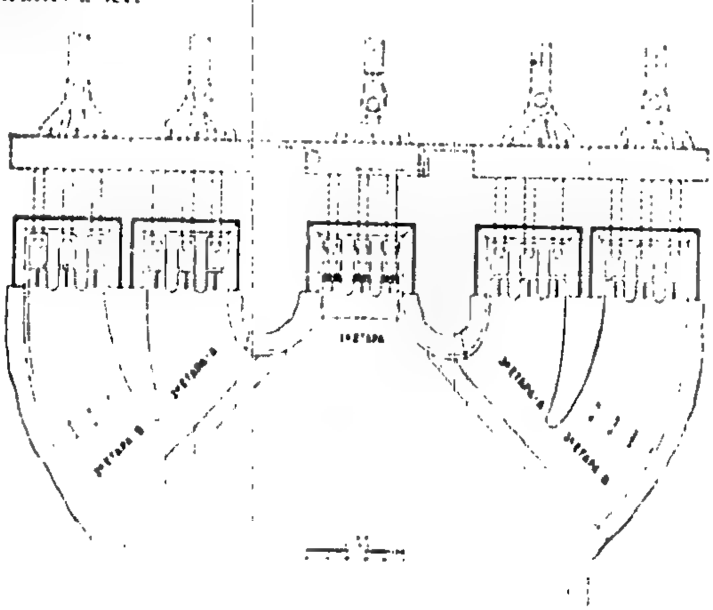

Fig. 6 — PAULO AFONSO — Disposition de la prise d'eau

Comme on voit sur la fig. 6 les étapes futures seront exécutées par moitiés; les parois qui provisoirement guident l'eau vers la première étape seront détruites et des batardeaux seront placés entre les piliers des étapes B.

SALLE DES MACHINES SOUTERRAINE

La salle des machines a été placée en souterrain pour plusieurs motifs dont les principaux sont:

- équipement d'une plus grande chute sans protection spéciale contre les crues, facilitant ainsi la localisation de l'usine;
- réduction de la longueur des conduites;
- moindre coût et plus grande sécurité pour celles-ci;

- moindre coût d'entretien des ouvrages de genre civil;
- [illegible] cas de raids aériens, pour les parties vitales et importantes de l'installation;
- moindre quantité de matériel à transporter (surtout fleurets et dynamite);

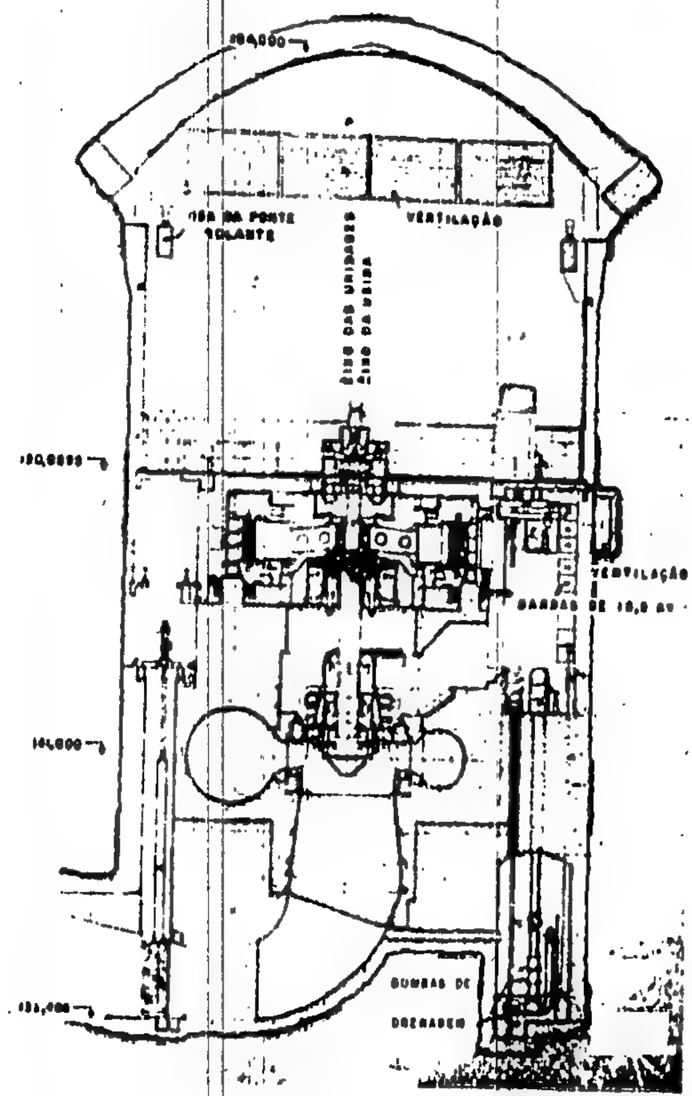

Fig. 7 — PAULO AFONSO — Coupe Transversale de l'usine

- moindre coût de l'installation car les excavations sont des opérations très économiques.
- emploi immédiat de la roche retirée des excavations, pour pré opérations très économiques;

Nous n'insisterons pas sur ces avantages parce qu'ils sont déjà bien connus des techniciens et que l'usage de ce type d'usines se généralise (Norvège, Suède, Italie, Mexique, France, Canada, Nekato avec 1.800.000 KW, etc.) quand les conditions locales le permettent.

Dans un travail présenté par l'ingénieur Domingos Marchetti dans cette section-ci de la Conférence Mondiale de l'Energie, sont étudiés les procédés employés dans les excavations souterraines (Fig. 7).

La salle des machines, synthétiquement, se compose d'une galerie avec un plafond en arcs paraboliques et des colonnes latérales qui supportent les poutres d'appui des deux ponts roulants de 130 tonnes chacun. Elle a trois étages: un à la côte 111 où se trouvent les appareils auxiliaires des turbines, un autre à la côte 115,165 qui correspond à la base des alternateurs, et enfin un dernier à la côte 150,059 – le hall des alternateurs proprement dit où émergent les excitatrices et où se trouvent les commandes des régulateurs et quelques autres équipements auxiliaires.

Entre les arcs qui soutiennent la voûte de l'usine a été placée une grille en cornières et fers ronds sur laquelle s'appuiera la toile du stuc de revêtement. Ce dispositif empêchera la chute des blocs qui pourraient se détacher de la voûte, quelle que soit leur taille, et évitera les sous pressions.

Plus tard seront creusées deux salles des machines de longueur double de l'actuelle, situées de chaque côté de celle-ci et contenant chacune 6 alternateurs de 60.000 KW. L'installation totale aura donc 15 x 60.000 = 900 000 KW.

VANNES DE SECURITE

En aval des tubes d'aspiration des turbines se trouve la cheminée d'équilibre – dont il n'est pas besoin d'expliquer la présence aux techniciens spécialisés – puis le tunnel de fuite qui a été revêtu de béton afin d'éviter l'érosion de quelques couches de roches de faible tenue. A la sortie du tunnel ont été placées deux vannes de sécurité, planes, de 1,93 x 11 mètres qui permettront son vidage en vue d'inspection ou de réparation.

PARTIE ELECTRIQUE

Le schéma de la partie électrique est classique, alternateurs triphasés de 61.225 KVA, 13.800 Volts, 60 périodes, connectés directement au banc des transformateurs monophasés de 22 500 KVA chacun, qui élèvent la tension à 220 000 Volts.

Sectionneurs et disjoncteurs à huile (un réservoir par phase) permettent de faire les manoeuvres des jeux de barres "service" et "auxiliaires". Sur la basse tension sont branchés les transformateurs de service. Des armoires d'acier abritent l'appareillage auxiliaire et, dans la salle de commande, un pupitre de manoeuvre permet d'effectuer toutes les opérations comme ouverture des vannes secteur, variations de vitesse des groupes, réglage de la tension, etc. exception faite de la mise en route des machines qui est manuelle. Etant donné la grande extension des lignes de transmission, les alternateurs ont un rapport de court-circuit de 1.89 qui est très élevé mais assure une ample marge réglage. Le télécommunication avec les sousstations est du système "Carrier".

CAMPEMENT

Vu la distance entre Paulo Afonso et les centres importants (Récife, Salvador) la CHESF a dû construire un campement de grandes proportions qui abrite 5.000 habitants où sont installés les différents services de la CHESF: magasins, bureaux, ateliers, laboratoires; les services sociaux: poste de puériculture, hôpital, écoles, église, clubs, terrains de sport, restaurant, coopérative, salle de réception des visiteurs; enfin les demeures du personnel dirigeant, des fonctionnaires et des ouvriers. Les constructions couvrent 51 231 m², divisés en 895 édifices.

EQUIPEMENT

Nous citerons seulement "pro memoria" l'équipement de construction considérable employé dans cette usine qui est presque complète en sa première étape. Cet équipement se compose de deux stations de concassage et betonnage, de derricks, de grues mobiles (Marion) dumpsters, camions, bennes pour le beton, compresseurs d'air, tracteurs, transformateurs électriques, moteurs, pompes, machines à souder, groupes électrogènes, etc.

TRANSPORTS

Un des problèmes les plus sérieux que la CHESF a dû résoudre a été celui des transports. Tout, depuis la nourriture jusqu'aux machines lourdes a dû être transporté par camion sur 500 km de distance. Environ 50 véhicules de tailles diverses ont transporté 62.000 tonnes sur plus de 5 millions de kilomètres, en dehors de ceux utilisés pour le transport local.

COÛT ET DURÉE DES TRAVAUX

L'usine de Paulo Afonso, en comptant les équipements de chantier et de transport, le campement, les dépenses générales et d'administration, excluant bien entendu les lignes et sousstations d'arrivée, coûtera (devis

récemment réajusté avec déjà 85% des ouvrages et des montages prêts) [illegible] par KW installé à la fin de la première étape (après l'installation de la 3ème unité de 60.000 KW). Il est à remarquer que le barrage, les routes, les ponts et les divers équipements serviront à équiper la puissance totale de 900.000 KW.

Tous les travaux, excepté le campement, auront été exécutés dans le délai de 4 ans, ce qui, étant donné les difficultés locales de toute sorte, paraît assez raisonnable.

ASSISTANCE SOCIALE

Avant d'arriver aux conclusions nous ne voulons pas omettre ce chapitre qui à notre avis est très important: l'assistance sociale. A Paulo Afonso la CHESF a fait organiser tout ce qu'elle a pu sur cette matière, à savoir: assistance médicale, salaires franchement supérieurs à ceux en cours dans la région, écoles primaires et même lycée, poste de puériculture, restaurant à bon marché, coopérative, vendant pratiquement au prix coûtant, assurance contre accidents même en dehors des travaux, église, divertissements, clubs, cinéma, visites aux chantiers pour les familles des travailleurs, etc.

Ainsi faisant nous touchons à la fin des travaux sans avoir eu une seule grève et même pas ce que la loi brésilienne appelle une "réclamation collective".

CONCLUSION

Cet exposé montre qu'il est possible d'exécuter dans des endroits lointains et presque sans ressources locales, des travaux importants dans des délais raisonnables et sur de très bonnes bases économiques à condition de:

1) – Bien étudier le projet et organiser les chantiers;
2) – Ne pas prétendre mettre en oeuvre des procédés trop orthodoxes, mais au contraire bien tenir compte des conditions locales;
3) – Donner aux dirigeants directs des travaux la plus ample autonomie technique et administrative;
4) – Conduire les travaux en imposant une discipline rigide mais très humaine;
5) – Placer le personnel de toutes catégories dans les meilleures conditions de confort physique et d'hygiène, et aussi d'ambiance spirituelle;
6) – Et finalement pratiquer une très ample assistance sociale et même morale aux travailleurs, surtout aux plus modestes.

RÉSUMÉ

Il existe dans le Nord-Est du Brésil une vaste région, pauvre actuellement, mais qui pourrait se développer moyennant l'aménagement de ses ressources hydrauliques qui se concentrent dans une zone de faible étendue dont la concession a été attribuée à la "Companhia Hidro-Elétrica do São Francisco". Cette compagnie a choisi la chute de Paulo Afonso pour commencer son programme d'aménagement.

L'usine hydro-électrique de Paulo Afonso utilise une dénivellation de l'ordre de 80 mètres dont l'équipement complet (après régularisation du haut São Francisco) pourra produire annuellement près de 6 milliards de KWH.

Le barrage qui coupe le fleuve en amont des chutes est de faible hauteur moyenne et de grande longueur. Il limite un bassin de décantation et canalise les eaux vers la chambre de mise en charge. Les évacuateurs de crues vannes et déversoir ont une capacité de 20.000 m³/sec. La prise d'eau a été prévue pour permettre une exécution facile des futures extensions.

La salle des machines a été construite en souterrain pour diverses raisons. Elle abrite 3 groupes verticaux de 60.000 KW. Plus tard, deux usines ayant chacune 6 groupes de 60.000 KW seront creusées à ses côtés. Le poste haute tension se trouve à la surface; il en part deux lignes à 220.000 Volts vers Récife et Salvador.

Pour faciliter la vie des travailleurs dans un chantier aussi éloigné de tout centre important, il a été créé un vaste campement pourvu de toutes les commodités.

L'un des problèmes les plus sérieux qui a préoccupé la CHESF a été le transport, Paulo Afonso se trouvant à 500 km des grands centres et n'ayant que très peu de ressources propres.

Malgré tout, le prix de revient du KW installé sera très bas et les délais d'exécution raisonnables.

Les bons résultats obtenus sont attribués à une bonne organisation technique et à une assistance sociale rationnelle qui créèrent une ambiance de travail des plus favorables à la production.

RESUMO

Existe no Nordeste Brasileiro uma vasta região atualmente pobre mas que pode se desenvolver mediante o aproveitamento das fontes de energia hidráulica, que se concentram numa zona de extensão reduzida, cuja concessão foi atribuida à Companhia Hidro Elétrica do São Francisco. Essa Companhia escolheu a cachoeira de Paulo Afonso para começar seu programa de aproveitamento

A usina hidroelétrica de Paulo Afonso utiliza um desnível da ordem de 80 metros, cujo aproveitamento completo (depois da regularização do Alto São Francisco) poderá produzir anualmente cêrca de 6 bilhões de KWH.

A barragem que represa o rio a montante das quedas tem uma pequena altura média e uma extensão considerável. Ela limita uma bacia de decantação e canaliza as águas para a caixa de pressão. Os órgãos de evacuação das enchentes — comportas e vertedouro — têm uma capacidade para 20.000 m³ seg. A tomada d'água foi prevista de maneira a tornar fácil a execução das extensões futuras.

A sala de máquinas foi construída em subterrâneo por várias razões. Ela abriga 3 grupos verticais de 60 000 KW. Mais tarde, duas usinas com 6 grupos de 60 000 KW cada uma, serão escavadas a seus lados. O pôsto alta-tensão fica na superfície e dêle saem duas linhas de 220 000 Volts para Recife e Salvador.

Para facilitar a vida dos trabalhadores num canteiro tão distante de qualquer centro importante, foi construído um acampamento provido de tôdas as comodidades.

Um dos mais sérios problemas que teve a CHESF que enfrentar foi o dos transportes, pois Paulo Afonso fica a 500 km dos grandes centros e tem poucas possibilidades próprias.

Apesar disso, o custo do KW instalado será muito baixo e o prazo de execução razoável.

Os bons resultados obtidos são atribuídos a uma boa organização técnica e a uma assistência social racional, que criaram um ambiente de trabalho dos mais favoráveis à produção.

SUMMARY

There exists in the Northeast of Brazil an extensive region at present poverty stricken; it can be developed, however, with the utilization of the sources of hydraulic energy, which concentrate in a zone of short extension, the concession of which was awarded to Companhia Hidro-Elétrica do São Francisco. This company selected the Paulo Afonso Water Falls to start its program of development.

The Paulo Afonso hydro-electric power plant utilizes a fall of about 80 m of water, the complete development of which (after the regularization of the High São Francisco) will make possible an annual production of about 6 billions of KWH.

The dam that holds up the river course upstream of the fall is of average small height but of considerable extension. It limits a decantation basin and canalizes the waters to a pressure intake. The devices for the control of the flood waters — crest gates and spillway dam — have a capacity of 20,000 m³/sec. The water intake was forecast with a view of facilitating the execution of future extensions.

The Power House was built underground for various reasons. It shelters three vertical sets of 60,000 KW. In the future, two power houses, each with 6 sets of 60,000 KW, will be excavated at its sides. The high-tension installation is built out-door and two 220,000 Volt lines issue from it and reach Recife and Salvador respectively.

To make life more agreeable for the workmen in such a remote site, far from any important center, there was built a camp supplied with all comforts.

One of the most serious problems faced by CHESF was transportation, inasmuch as Paulo Afonso is 500 km distant from the large Northern centers and because of the limited local possibilities.

In spite of the above, the cost of the installed KW will be very low and the period of execution reasonable

The good results obtained are attributed to a good technical organization and a rational social assistance which created an atmosphere of work most favorable to production

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MORIZOT (R.)
(França)

LA POLITIQUE DE PLEIN EMPLOI DES CALORIES DANS L'INDUSTRIE SIDÉRURGIQUE LORRAINE

Par R. MORIZOT

[illegible]

COMITÉ NATIONAL FRANÇAIS

La Sidérurgie est une industrie qui enfourne deux produits de base, le minerai et le charbon; elle doit sortir de l'acier du premier avec l'utilisation la plus complète possible de l'énergie latente contenue dans le second: dans cette profession, la qualité du compte d'exploitation est en liaison directe de celle du bilan "calories".

C'est là un lieu commun: il a cependant paru utile de le mettre en exergue d'un exposé sur les résultats obtenus par les usines du Bassin Sidérurgique Lorrain qui, depuis quelques années, ont systématiquement transposé à l'échelle collective les principes de plein emploi énergétique appliqués auparavant à l'échelle individuelle.

Le Bassin Sidérurgique Lorrain comprend 18 usines, dont les hauts-fourneaux et aciéries sont répartis sur un territoire s'étendant d'environ 40 kilomètres du Nord au Sud et 30 kilomètres de l'Est à l'Ouest.

Dès le lendemain de la guerre 1914-18, où la destruction des mines du Nord de la France rendait l'approvisionnement en charbon du pays particulièrement rare, la Sidérurgie de ce Bassin dut résolument s'engager dans le double programme: économies relatives à l'utilisation calorifique et mécanique des tonnages de houille enfournés d'une part, production d'énergie électrique avec le gaz non sidérurgiquement employé d'autre part.

Sur la première partie de ce programme, il ne sera rien dit; l'histoire des progrès réalisés et des solutions adoptées étant celle qu'ont vécu et vivent tous les Sidérurgistes du monde avec leur souci constant de la chasse aux calories; mais en réalité, elle n'a cessé d'être étroitement jumelée à la seconde. En effet, pour un sidérurgiste le bilan "énergie" est unique, jusques et y compris l'utilisation du courant électrique, au

point que la conduite méthodique d'une exploitation de ce genre ne se [illegible] au contrôle combiné englobant à la fois la chaleur des gaz et la valorisation à chaque instant des kilowattheures produits.

Il était donc bien dans la logique des choses, que, en même temps que se réalisait le développement intérieur des usines sidérurgiques du Bassin avec la recherche du rendement maximum des calories, se posât parallèlement le double problème de la meilleure utilisation des énergies disponibles et des moyens de parer aux défaillances des centrales électriques individuelles: c'est pour y répondre que fut, dès cette époque, construit un vaste réseau de liaison à 60 KV assurant la marche en parallèle de celles-ci. Si la chose est soulignée ici, c'est moins pour le fait que cette oeuvre fut entreprise à une époque, où on en était aux premiers balbutiements de l'interconnexion, que pour l'esprit de coordination et de solidarité sidérurgique qui l'inspire et dont nous verrons après les fruits qui en ont été la conséquence.

Les résultats heureux s'en sont fait rapidement sentir et cela à raison même du caractère exceptionnellement variable des productions des centrales sidérurgiques. Amélioration de l'utilisation générale grâce aux compensations des diagrammes inter usines, économie d'investissement grâce aux garanties de secours apportées à chacun par la mise en commun des ressources.

C'est ainsi qu'en 1934, alors que la production totale aciers avait été de 4.800.000 Tonnes de fonte et 4.117.000 d'aciers, la production d'électricité des usines raccordées atteignait 887 millions de kilowattheures, dont 690 produits par les adhérents pour eux-mêmes, 60 millions ayant été échangés à titre de secours réciproque et 138 pour être vendus en dehors du réseau sidérurgique. Le nombre de kilowattheures produit par tonne d'acier élaborée était à cette époque pour l'ensemble du Bassin de moins de 210 kilowattheures.

Nous ne dirons que pour mémoire les problèmes difficiles qui durent être résolus à ce moment-là pour assurer la marche en parallèle des groupes électrogènes à turbines et à moteurs à gaz, du fait des conditions inégales d'inertie et de statisme de ces deux natures d'engins et de l'importance extrêmement grande des à coups de puissance instantanée provoqués par les outils sidérurgiques: ceux-ci furent progressivement résolus, mais pour une bonne part grâce à l'évolution de la technique et l'orientation prise par les producteurs du Bassin, de substituer aux moteurs à gaz, malgré l'excellence de leur rendement, les groupes turbo-alternateurs de puissance unitaire plus élevée, apportant ainsi un des éléments appréciables de stabilité dans la conduite du réseau.

Il faut ici reconnaître que la mystique du groupement au sein du Bassin, qui n'était encore une fois que l'aboutissement logique d'une politique d'économies longuement poursuivie par chacun, a été plus forte que ces difficultés passagères et que la persévérance qu'il a fallu pour les

Malgré, apporte la justification qu'il y avait dans ce principe de coordination [illegible] un ferment certain de progrès et de meilleur emploi pour l'avenir.

Qu'était en effet devenue la situation en 1948 au lendemain de la remise en état du potentiel sidérurgique du Bassin Lorrain fortement ébranlé par les événements de la guerre 1940-45? Le tableau ci-après en donne du point de vue énergie les éléments essentiels.

Fonte produite	1 627 000 Tonnes	
Coke enfourné	1 987 000	(soit au mille 1078)
Energie produite	1 311 000 KWH	
KWH produits à la T. de fonte	291 KWH	
Consommation totale d'énergie	1 230 millions KWH	
Disponible pour le réseau extérieur	111 millions KWH	

On voit tout de suite que pour une production pratiquement identique de fonte entre 1931 et 1948, l'énergie produite dans les usines passe cependant de 887 à 1 311 millions de kilowattheures soit une augmentation de près de plus de 50%, laissant par ailleurs sensiblement identique le montant de l'énergie débitée sur le réseau extérieur (111 millions en 1948 contre 138 en 1931).

Il faut voir dans ces résultats, tout d'abord l'effort d'électrification poursuivi dans les usines du Bassin durant ces quinze années, ensuite le fait que l'accroissement des besoins en énergie qui en est résulté, a pu être entièrement couvert par les centrales sidérurgiques individuelles, lesquelles étaient modernisées ou suréquipées dans le même laps de temps.

C'est là un tribut normal payé au progrès par une industrie aussi hautement évolutive que l'est l'industrie sidérurgique; il n'aurait donc pas mérité d'être signalé, si cette augmentation massive des kilowattheures produits dans le Bassin, de 1948 par rapport à 1931, n'avait en fait été obtenue que par prélèvement, sans pratiquement de secours extérieur, sur la masse de calories incluse dans le charbon et le coke enfournés, et qui se trouve avoir été sensiblement la même pour chacune de ces deux années de comparaison.

Ceci est une donnée tangible de l'amélioration qu'a apportée l'interconnexion électrique dans ce Bassin. pour des centrales hydrauliques ou thermiques minières, l'interconnexion constitue une des conditions nécessaires et préalables de leur établissement, créées qu'elles sont, le plus souvent, pour écouler une énergie que le site ou les servitudes économiques leur imposent de faire sur place.

Pour des aciéries, comme celles du Bassin Lorrain, la production d'énergie n'est qu'un moyen de valorisation de calories disponibles, et l'interconnexion que la transposition à l'échelle collective d'une politique d'économies achevée à l'échelle individuelle; c'est dire que pour tout sidérurgiste, les efforts financiers qu'il est amené à faire dans des

oeuvres l'association de ce genre, s'analysent uniquement par le crédit [illegible] inscrire, suivant les circonstances, à son propre bilan calorifique

La voie ouverte par ce programme d'interconnexion électrique ne pouvait s'arrêter là: sans doute, a-t-il contribué à pallier dans une certaine mesure l'absence de synchronisme entre la production des gaz et leur utilisation, à assurer des secours réciproques aux aciéries mises en parallèle et ainsi réduire les équipements de sécurité qu'elles eussent été dans l'obligation de faire en marche isolée, à permettre une valorisation des gaz, qui, sans leur transformation en énergie électrique et le déversement de cette dernière sur le réseau commun, eussent été définitivement perdus; il n'en est pas moins appa[illegible] dès le lendemain de la guerre, que des améliorations devaient encore être apportées à ces premiers résultats et qu'il fallait aborder une nouvelle étape de valorisation des gaz de l'ensemble du Bassin

Une première donnée de fait s'imposait: la consommation moyenne des calories par kilowattheure produit dans les Bassin était en 1918 de plus de 5.000, sans parler de pertes appréciables aux gueulards et aux brûleurs. Or, la puissance nécessaire au fonctionnement de la majorité des Aciéries est en général de l'ordre de 10 à 25.000 kilowatts, et celles-ci l'assuraient avec des unités types 10.000 kilowatts, parfois de puissance unitaire moindre, d'où cette consommation spécifique élevée. Il n'était donc pas possible à l'échelon de l'établissement isolé, de profiter dans leur plénitude des avantages de rendement des groupes modernes types 50.000 et 100 000 kilowatts, sauf à admettre le principe de concentrer dans une seule centrale, la production d'énergie nécessaire au fonctionnement de plusieurs établissements sidérurgiques pas trop éloignés l'un de l'autre.

Mais la rançon fatale d'une telle conception est dans l'obligation d'établir des conduites de gaz reliant ceux-ci à la Centrale Commune et comportant de ce fait un supplément d'investissement d'autant plus lourd à la calorie transportée que le pouvoir calorifique du gaz hauts-fourneaux transporté est faible (950 calories au mètre cube).

Force a donc été de s'engager dans cette formule nouvelle d'association, avec toute la prudence qu'exigeait la mise en balance des avantages d'une amélioration générale du rendement (c'est-à-dire de valorisation des calories) avec les charges financières d'une centrale commune assortie d'un réseau gaz onéreux, ces charges étant elles-mêmes à comparer à ce qu'elles auraient été si les aciéries avaient persévéré dans le développement et la modernisation de leurs centrales individuelles.

C'est en partant de ces considérations fondamentales qu'ont été créées dans le Bassin deux centrales communes: la première d'Hersetange, mise en service en 1951, comportant deux groupes de 40.000 kilowatts, qui seront complétés par une unité identique dans un proche avenir et collectant le gaz de 4 usines du Bassin de Longwy; la deuxième de Richemont, mise en service cette année, équipée au départ avec deux

groupes de 50.000 kilowatts et prévue pour une puissance totale de 200.000 [illegible] cinq usines de la vallée de la Moselle et de l'Orne, produisant l'énergie pour le compte de sept aciéries parmi lesquelles figurent naturellement les cinq émettrices de gaz.

Il est à peine besoin de dire que lorsque s'est posé le problème de création de ces groupements énergétiques, les considérations de rentabilité précédemment exposées, n'ont été qu'un élément important, mais non le seul, de la décision prise, tant il est vrai qu'une oeuvre d'interconnexion, qu'elle soit en électricité ou en gaz, comporte un potentiel de plein emploi qui se révèle à l'usage presque toujours plus fructueux qu'on ne l'ose prévoir.

Quoiqu'il en soit, et sans vouloir donner à ces chiffres un sens autre que celui de renseignements indicatifs, le transport de gaz, conduites plus surpresseurs, représente une charge par mètre cube entrant à la Centrale commune, d'environ 15% pour Hersevange et 20% pour Richemont de son prix évalué sur la base de la parité calorie charbon, et cela en ne tablant que sur les 80.000 kilowatts installés actuellement dans la première et 100.000 dans la seconde. Ces données fixant pour l'immédiat, et du seul point de vue financier, l'intérêt de l'opération, les économies d'investissement et d'exploitation qu'apporte la centrale commune à fortes unités par rapport aux groupes individuels, qu'ils soient anciens ou nouveaux, compensant plus que largement les surprix attachés aux transports de gaz qu'elles imposent inéluctablement.

Mais encore une fois, ces communautés énergétiques ainsi créées se doivent aussi d'être analysées en considération de leurs avantages subsidiaires, qui pour n'être le plus souvent chiffrables qu'après coup, n'en sont pas moins d'une importance telle qu'ils sont en train de donner à l'exploitation énergétique du Bassin une physionomie entièrement nouvelle et un caractère de plein emploi indiscutable. Nous les énumérons brièvement:

1.° - La Centrale commune est au premier chef un outil d'interconnexion gaz. L'interconnexion électrique qui existait auparavant entre les centrales individuelles, aurait exigé pour utiliser l'intégralité des disponibilités de gaz de chacun une charge d'équipement hors de proportion avec l'énergie supplémentaire dégagée. Au contraire, la Centrale commune met effectivement en parallèle un grand nombre de hauts-fourneaux, soit par exemple 16 dans le cas d'Hersevange, 21 dans le cas de Richemont, même en période normale, le diagramme d'émission de gaz de chaque usine témoigne, après couverture de ses besoins propres, d'oscillations importantes instantanées ou en cours de la journée. La superposition des diagrammes, que réalise la mise en commun des ressources gaz, aboutit à une régularisation profitable sans laquelle du gaz risquerait d'être perdu chez chacun des adhérents.

De même les N hauts-fourneaux de la Centrale commune consti [illegible] de gaz. Si l'une d'elles vient à s'interrompre, elle ne perd que $\frac{1}{N}$ de sa fourniture, alors que la centrale individuelle intéressée en perd une fraction beaucoup plus importante, sans les possibilités de récupération sur les émissions de gaz des N − 1 autres hauts-fourneaux restés en ordre de marche.

2° - La création de l'interconnexion gaz d'une centrale commune, avec l'action des surpresseurs rendant constante la pression du gaz aux divers appareils utilisateurs des usines raccordées, assure chez celle-ci le maximum de régularité et d'économie. C'est là un avantage difficile à chiffrer, mais hautement apprécié par les Aciéries dont on sait les dispositions qu'elles ont été obligées d'adopter pour réaliser cette constance de pression: gazomètres, régulateurs, moyens de chauffage complémentaires intervenant automatiquement, etc.

3° - Enfin l'interconnexion gaz, créée à la faveur d'une centrale commune, constitue en cas de défaillance de hauts-fourneaux d'une usine, une ressource de sécurité permettant la couverture en gaz de ses besoins sidérurgiques internes, alors que pour pallier de telles défaillances, elle est en général obligée d'installer des moyens de chauffage auxiliaires, toujours onéreux, pour se substituer instantanément au gaz manquant. Là encore, cet avantage ne saurait être évalué à priori, mais il est indéniable qu'il y a dans ce dispositif un élément certain de valorisation du gaz par la primauté qu'il permet de donner à la satisfaction des besoins sidérurgiques internes des aciéries raccordées.

Tout ceci corrobore l'exact classement des valeurs que la sidérurgie entend donner aux quantités de chaleur latente des résidus de fabrication, et qui veut que la production d'énergie électrique apparaît en dernière place dans cette hiérarchie. Sous une autre forme, les volumes de gaz mis à la disposition des centrales sont constitués par les excédents des productions de chaque usine sur leurs consommations; par conséquent, l'énergie fabriquée avec cette différence (qui est en moyenne de l'ordre de 25% de la production gaz) subit entièrement la répercussion des oscillations prévues ou imprévues survenant dans chacun de ces deux termes. Cet assujétissement, qui aboutit à conférer à l'énergie faite au gaz de hauts-fourneaux un véritable caractère de fil de l'eau, aggravé encore par les fluctuations cahotiques de tous les instants, trouve atténuation dans les centrales communes ainsi qu'il vient d'être expliqué.

Mais il n'en appert pas moins que cette incertitude ne cesse de constituer une véritable hypothèque quant à la qualité à attendre de l'énergie produite, un aléa certain quant aux choix des unités à installer et à leurs perspectives de rentabilité au cours des années de leur existence. Faut-il ajouter enfin que les crises économiques se font particulière-

ment senti sur les industries de base comme l'est la Sidérurgie et qu'il [illegible] les alternances de sécheresse et d'humidité que l'on rencontre dans tout aménagement hydraulique.

Enfin à tous ces motifs d'irrégularité et d'incertitude s'en ajoutait un dernier: les répercussions que les recherches sidérurgiques en cours peuvent avoir sur le bilan énergétique des usines sidérurgiques.

L'enrichissement des minerais, la construction de bas fourneaux, pour ne parler que des deux plus importantes, pourraient dans l'avenir réduire d'une façon notable la production de gaz, et le risque de cette éventualité, bien que lointaine, s'est ajouté aux raisons précédentes pour doter les nouveaux générateurs électriques de chaudières à combustion mixte gaz-charbon.

Ainsi ces centrales communes, grâce au stock de charbon dont elles disposent, à la substitution automatique en cours de marche du combustible solide au combustible gazeux, ont tous les aspects de centrales hydrauliques dont les mêmes groupes pourraient indifféremment et simultanément fonctionner avec l'eau de la rivière et celle d'un réservoir d'accumulation: c'est dire les services considérables à attendre de ces équipements nouveaux qui, moyennant un surprix d'investissement négligeable, sont parés pour obvier aux oscillations instantanées, aux fluctuations cycliques, aux risques de manquements définitifs, et pour garantir aux aciéries raccordées la satisfaction de leurs besoins internes, sans que la qualité de l'énergie produite, qu'elle soit pour leur alimentation propre ou pour le déversement sur les réseaux extérieurs, en soit dépréciée.

Cette conception parachève l'oeuvre de plein emploi de la calorie que le Bassin avait amorcée en créant jadis les liaisons électriques intercentrales: empreinte d'une profonde idée de communauté, elle apporte à chacun avec un coefficient de rendement d'usage extérieur de son gaz, considérablement augmenté, par rapport à ce qu'il aurait obtenu en agissant isolément, le triple avantage d'une tenue sûre, régulière et économique de son bilan calorifique.

TABLEAU I

[illegible]	47 [illegible]	5 50[illegible]	1 600	4 143	86 [illegible]	2 68[illegible]	[illegible]
[illegible]	[illegible]	5 026	1 796	4 4[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	2 [illegible]	[illegible]	[illegible]	[illegible]	340
[illegible]	[illegible]	5 944	2 [illegible]	4 [illegible]	[illegible]	[illegible]	[illegible]

Le Tableau I ci-après donne les améliorations obtenues à l'échelle [illegible] des quatre années 1950, 1951, 1952 et 1953, étant fait observer que l'entrée en action de la centrale commune d'Herserange n'a commencé qu'en 1951, avec les productions annuelles ci-après:

en 1951 de 34 millions de KWH sur un total de production du Bassin de 1 790 millions

en 1952 de 393 millions de KWH sur un total produit de 2 197 millions

en 1953 de 574 millions de KWH sur un total produit de 2 316 millions

On voit que pour un taux de calories enfournées à la tonne acier, resté sensiblement identique pour les quatre années en cause, la production de kilowattheure unitaire est passée de 290 à 361 et la calorie consommée par kilowattheure s'est abaissée de 1.713 à 1.039; une nouvelle étape sera franchie à partir de 1954 qui marquera la mise en service des 100.000 kilowatts de Richemont et d'un autre groupe individuel de 25.000 kilowatts tous deux équipés en chaudières mixtes gaz-charbon. A la lumière des résultats obtenus, il est permis d'escompter qu'à ce moment le Bassin aura une consommation spécifique moyenne de l'ordre de 3.200 à 3.300 calories, et une production d'énergie de plus de 400 kilowattheures à la tonne d'acier.

Sans doute, ces résultats ne donnent-ils qu'une vue incomplète, parce que noyés dans l'ensemble, des améliorations apportées par une centrale commune à l'échelle des aciéries qui l'ont créée.

Le tableau II ci-après fait toucher du doigt les avantages recueillis par l'ensemble des Etablissements sidérurgiques groupés dans la Centrale commune d'Herserange, encore que ceux-ci, pour des raisons de sécurité principalement, aient été amenés à maintenir certaines de leurs vieilles unités en service.

TABLEAU II

		1938	1950	1953
1 — [illegible]		[illegible]	[illegible]	1 ?56000
2 — [illegible] des centrales [illegible] des Aciéries	10^6 KWH	2?3	?0?	1?3
3 — [illegible]	10^6 KWH	2??	303	4?2
4 — [illegible]	KWH	24?	?08	235
5 — [illegible]	10^6 KWH	12	28	9?4
6 — [illegible] (2+5)	10^6 KWH	273	328	726
7 — Total de l'énergie [illegible] la Communauté (6-3)	10^6 KWH	34	?4	314

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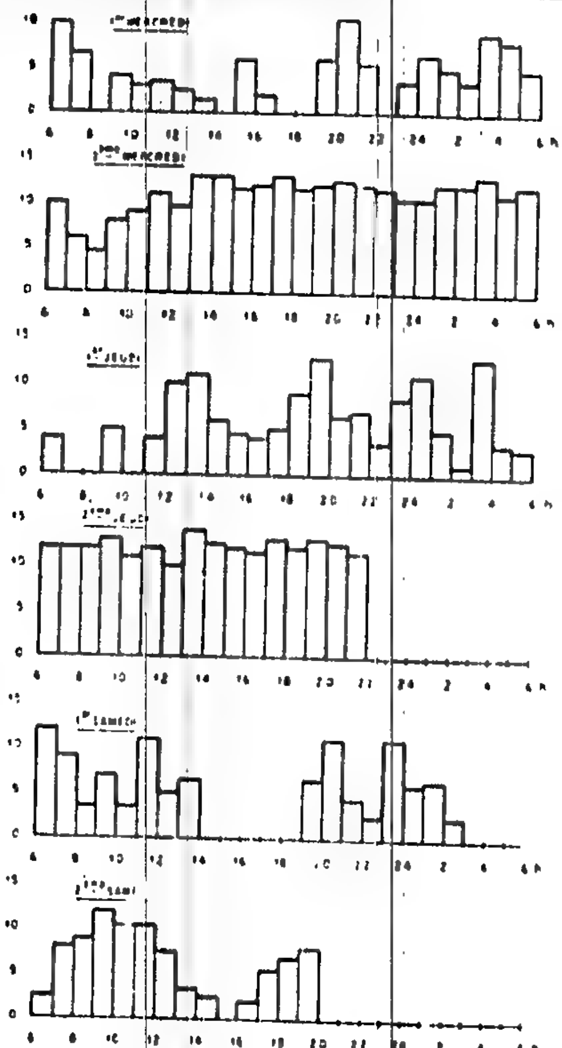
CPYRGHT

TABLEAU III

[illegible] UNE CENTRALE COMMUNE



NOTA

LES DIAGRAMMES CI-CONTRE REPRESENTENT LE CHARBON CONSOMME [illegible] PAR HEURE DANS UNE CENTRALE COMMUNE POUR PALLIER SOIT AUX DEFAILLANCES DE [illegible] DE LA CENTRALE [illegible] LA DEMANDE [illegible] A UNE DEFAILLANCE DE L'ENSEMBLE DU RESEAU.

[illegible] INTERVALLE ENTRE LE 1er MERCREDI ET LE 2ème [illegible] MEME POUR LES JEUDI ET SAMEDI.

LA PREMIERE SEMAINE ETAIT NORMALE LA SECONDE SUJETTE A DE NOMBREUSES DEFAILLANCES DUES AU FROID.

IL FAUT TENIR COMPTE AUSSI DANS L'INTERPRETATION DE CES DIAGRAMMES DE L'INFLUENCE DE LA ROTATION DES POSTES [illegible] ET [illegible].

L'installation décidée d'un troisième groupe à la Centrale d'Hersé [illegible] la mise en veilleuse, de centrales individuelles, aboutissant à ce que le gaz qu'elles avaient utilisé en 1953 pour produire 153 millions de kilowattheures soit dirigé sur la centrale commune, ainsi sera dégagée une production supplémentaire, sous réserve que la consommation interne des Aciéries reste inchangée, soit 65 millions de kilowattheures portant le total de l'énergie susceptible d'être fournie à l'extérieur, à près de 200 millions de kilowattheures.

Cette oeuvre de coordination aboutit bien à la valorisation recherchée des gaz de hauts fourneaux disponibles chez les aciéries, mais on en mesure toute la portée par le fait que la combustion mixte gaz-charbon confère à cette énergie un caractère de régularisation qui en accentue substantiellement la valeur; il n'est pour s'en rendre compte, que la vue des diagrammes de la puissance faite au charbon (sur un total de 80.000 kilowatts) et qui donne pour deux semaines consécutives, prises au hasard, les variations d'intervention de charbon, sans laquelle l'énergie exportée aurait été gravement dépréciée.

Cette politique de plein emploi de la calorie, dont on a constaté les effets à l'échelle du Bassin d'abord, des groupements fédérés autour des Centrales communes ensuite, doit être enfin examinée du seul point de vue de l'aciérie. Pour ne pas alourdir ce rapport, le tableau IV donne l'exemple d'une aciérie adhérente de centrale commune dont on pourra comparer la répartition d'emploi de son gaz en 1938, 1950 et 1953.

TABLEAU IV

	1938	1950	1953
[illegible]	[illegible]	[illegible]	[illegible]
Gaz consommé en % de la production de gaz brut			
[illegible]	[illegible]	[illegible]	[illegible]
[illegible] gaz	[illegible]	7,2%	7,5%
Groupes électrogènes	[illegible]	16,5%	13,3%
Aciéries Thomas et Martin	3,9%	3,4%	2,5%
Fours	[illegible]	12,2%	11,3%
Chaudières d'aciéries et chauffage	[illegible]	19,5%	9,7%
Consommation totale usines	[illegible]	[illegible]	[illegible]
Gaz [illegible]	[illegible]	[illegible]	[illegible]
Pertes [illegible]	[illegible]	14,6%	[illegible]
	[illegible]	[illegible]	[illegible]

L'exposé d'ensemble qui vient d'être fait révèle les fructueux avan-tages [illegible] ont attendre de cette nouvelle étape de coordination que constitue la création des centrales communes.

En effet, du jour où elles auront pris leur place définitive dans le système énergétique du Bassin, des extensions en faveur d'autres aciéries vont pouvoir être apportées aux transports de gaz qu'elles ont rendu nécessaires au départ, et ceci sans parler des possibilités que chacune aura de substituer à sa production éventuelle au charbon la production de centrales voisines lorsque celles-ci auront du gaz et de la puissance machine en excès. Ainsi seront pleinement jumelés les effets de l'interconnexion gaz et de l'interconnexion électrique.

Résumé

Les usines du Bassin Sidérurgique Lorrain, ont, dans ces trente dernières années, systématiquement transposé à l'échelle collective les principes de plein emploi énergétique qu'elles poursuivaient auparavant à l'échelle individuelle. L'auteur du rapport trace les étapes successives de ces efforts.

Le premier pas fut franchi dans ce sens, au lendemain de la guerre 14-18, en créant un vaste réseau électrique interusines à 63 KV, qui aboutit rapidement à une amélioration considérable dans l'emploi du gaz, en même temps qu'était renforcée la sécurité d'alimentation au prix d'une économie sensible dans les investissements. C'est ainsi qu'entre 1931 et 1938, pour une production pratiquement identique de fonte, l'énergie produite dans les usines passa de 887 à 1 311 millions de Kilowattheures, soit une augmentation de 50 %. L'effort d'électrification poursuivi parallèlement dans les usines a eu pour conséquence un important accroissement des besoins en énergie, ceux-ci, grâce à l'économie et au plein emploi d'un montant de calories resté sensiblement le même, ont pu ainsi être entièrement couverts sans intervention extérieure.

L'interconnexion électrique des centrales sidérurgiques est particulièrement payante, par son effet palliatif sur les oscillations qui se présentent d'une usine à l'autre, entre consommateurs et producteurs de gaz, et ceci sans parler des avantages de secours réciproques que procure la marche en parallèle d'un nombre important de centrales, ramassées sur une aire géographique limitée.

Une seconde étape dans cette oeuvre de coordination fut marquée par la création des centrales communes, intervenue au lendemain de la Libération.

A la notion de centrales individuelles limitée aux puissances normalement nécessaires à l'établissement sidérurgique qui l'avait installée, a été substituée celle de la centrale commune, concentrant des groupes mo

dériés, en des points géographiquement choisis et comportant un réseau établissements sidérurgiques aux chaudières.

Les deux réalisations typiques ont été celle d'HERSERANGE (2 groupes de 10 000 kilowatts) et celle de RICHEMONT (2 groupes de 50.000 kilowatts), la première mise en service en 1951, la seconde cette année

Ces centrales s'avèrent des outils excellents d'interconnexion gaz, par la mise en parallèle qu'elles assurent directement d'un nombre important de hauts fourneaux: 16 dans le cas d'HERSERANGE, 21 dans celui de RICHEMONT; elles apportent, grâce à l'action de surpresseurs au départ des usines, une régularité et une économie dans l'emploi du gaz à l'intérieur des usines; elles constituent une ressource de sécurité permettant la couverture en gaz des besoins sidérurgiques internes de leurs adhérents, économisant ainsi chez eux les moyens de chauffage auxiliaires. Enfin elles sont prévues pour la marche mixte gaz-charbon qui leur donne tous les aspects de centrales hydrauliques dont les vieux groupes pourraient indifféremment et simultanément fonctionner avec l'eau de la rivière et celle d'un réservoir d'accumulation

En résumé, la centrale commune apporte le triple avantage, par rapport au régime de la centrale isolée, d'une tenue sûre, régulière et économique des bilans calorifiques des adhérents qui y participent

L'auteur termine par des données comparatives chiffrées sur les résultats obtenus par cette politique de coordination, tant du point de vue consommation spécifique par kilowattheure produit, que production d'énergie à la tonne d'Acier. le résultat le plus typique est que le Bassin, malgré l'accroissement important de ses besoins en énergie, consécutifs à sa modernisation, peut maintenant non seulement se suffire à lui-même, mais est en mesure de fournir à l'extérieur une puissance appréciable, parfaitement régularisée du fait de l'existence de ses centrales communes et cela par le seul emploi des calories dégagées de ses enfournements charbon

SUMMARY

During the last 30 years the power plants of the iron industry of the Lorrain basin have systematically applied on a collective basis the principles of the full use of energy which they had hitherto applied separately. The author of the Paper traces the successive stages in accomplishing this

The first step taken in this direction, immediately after the 1914-18 war, was the establishment of a vast network interconnecting the plants at 63 Kv which resulted rapidly in a considerable improvement in the use of gas, at the same time as the security of supply was increased with an appreciable economy in investment. Thus between 1931 and 1938, for an almost identical output of pig iron, the energy produced by the

stations rose from 887 to 1 331 million Kwh, or an increase of 50%. [illegible] the plants resulted in an important growth in the demand for energy, this demand has been fully met without outside intervention due to measures of economy and the full use of an amount of calories which has remained practically the same.

The interconnection of the siderurgical generating stations is specially remunerative by its equalising effect on the oscillations which arise in one or other plant, as between consumption and gas produced, without mentioning the advantages of mutual assistance afforded by the parallel operation of a number of important stations located in a limited geographical area.

A second stage in this work of coordination was marked by the erection of common generating stations undertaken after the Liberation.

The idea of individual stations limited in output to the normal requirements of the siderurgical plant which installed it was replaced by that of a common central station, equipped with modern units, built at a point suitably located geographically and comprising a network of gas pipe-lines running from the iron works to the boilers.

Two typical examples are the Hersetange station (2 groups of 10,000 kilowatts) and the Richemont station (2 groups of 50 000 kilowatts), the first put into service in 1951 and the second during the present year.

These central stations provide an excellent means of interconnecting gas sources, by placing directly in parallel an important number of blast furnaces: 16 in the case of Hersetange and 21 in that of Richemont. Due to the action of boosters at the point of leaving the works they lead to regularity and economy in the use of the gas within the works and they provide a margin of safety in assuming a sufficiency of gas for the internal needs of the supplying iron works, thus economising auxiliary means of heating. Lastly they are designed for mixed operation by either gas or coal which gives them characteristics similar to those of hydraulic stations where old groups could operate indiscriminately and simultaneously with water from the river and from a storage reservoir.

In short the common central station has a three fold advantage over the isolated station in that it assures a sure, regular and economical use of the thermal availabilities of the plants participating in the scheme.

The author concludes by giving comparative figures on the results obtained by this policy of coordination, both as to specific consumption per Kwh produced and energy produced for ton of steel. the most typical result is that the basin, despite the important increase in its requirements of energy, consequent on its modernisation, is not only self sufficient but is able to furnish an appreciable supply to the outside under perfectly regular conditions, due to the common central stations, and this by the sole use of the calories liberated by its furnaces.

As usinas da Bacia Siderúrgica da Lorraine, nos últimos trinta anos, sistemàticamente transpuseram para a escala coletiva os princípios de pleno emprêgo energético que antes almejavam na escala individual. O autor da monografia traça as sucessivas etapas dêsses esforços.

O primeiro passo foi dado, nesse sentido, após a guerra de 1914-1918, pela criação duma vasta rêde elétrica inter usinas a 63 KV, de que resultou, ràpidamente, um melhoramento considerável no emprêgo do gás, ao mesmo tempo que se via reforçada a segurança de alimentação ao preço duma economia sensível nos investimentos. Assim é que entre 1934 e 1938, para uma produção pràticamente idêntica de fundição, a energia produzida nas usinas passou de 887 a 1 314 milhões de kilowatt-horas, ou seja um aumento de 50%. O esfôrço de eletrificação prosseguido paralelamente nas usinas teve, em conseqüência, um importante acréscimo de necessidades em energia: isto graças à economia e ao pleno emprêgo dum montante de calorias sempre sensivelmente o mesmo, tendo se podido, assim, ficar inteiramente suprido sem intervenção exterior.

A interconexão elétrica das centrais siderúrgicas é particularmente lucrativa, pelo seu efeito paliativo sôbre as oscilações que se apresentam de uma usina a outra, entre consumidores e produtores de gás, e isto sem falar das vantagens de socorros recíprocos que atingem o funcionamento em paralelo de um número importante de centrais, coordenadas numa área geográfica limitada.

Uma segunda etapa nessa obra de coordenação foi marcada pela criação de centrais comuns, intervinda após a Libertação.

A noção de centrais individuais limitadas às potências normalmente necessárias ao estabelecimento siderúrgico que a tinha instalado, foi substituída pela de central comum, concentrando grupos modernos, em pontos geogràficamente escolhidos e comportando uma rêde de adução de gás indo dos estabelecimentos siderúrgicos às caldeiras.

As duas realizações típicas são a de Herserange (2 grupos de 40.000 kilowatts) e a de Richemont (2 grupos de 50 000 kilowatts), a primeira tendo entrado em serviço em 1951, e a segunda êste ano.

Essas centrais se apresentam como utensílios excelentes de interconexão de gás, pela coordenação paralela que asseguram diretamente a um número importante de altos-fornos: 16 no caso de Herserange, 24 no de Richemont. Graças à ação de compressores de refôrço na saída das usinas, essas centrais trazem regularidade e economia no emprêgo do gás no interior das usinas. Constituem um recurso de segurança permitindo o suprimento de gás para as necessidades siderúrgicas internas dos anexos, nêles economizando, assim, os meios de aquecimento auxiliares. Finalmente essas centrais são previstas para o funcionamento misto gás-carvão,

que lhes dá todos os característicos de centrais hidráulicas, e por onde os [illegible] ente e simultâneamente, funciona com água do rio ou dum reservatório de acumulação.

Em resumo, a central comum oferece a tríplice vantagem, em relação ao regime da central isolada: duma manutenção segura, regular e econômica dos balanços térmicos dos anexos que dela participarem.

O autor termina com dados comparativos cifrados sôbre os resultados obtidos por essa política de coordenação, tanto sob o ponto de vista do consumo específico por kilowatt-hora produzido, como sob o ponto de vista da produção de energia na tonelada de aço: o resultado mais típico sendo o da Bacia de Lorraine que, mau grado o aumento importante de suas necessidades em energia, consecutivas à sua modernização, pode agora não só se bastar a si mesma, como se encontrar pronta a fornecer para o exterior uma potência apreciável, perfeitamente regularizada pelo fato da existência de suas centrais comuns, e isso pelo simples emprêgo das calorias desprendidas dos seus enfornamentos de carvão.

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COMBET (G.)
BOLZINGER (A.)
França

REALISATIONS, DANS L'INDUSTRIE DU GAZ FRANÇAISE, CONCERNANT LA PRODUCTION, A PARTIR DES DÉRIVÉS DU PÉTROLE, DE GAZ ANALOGUES AU GAZ DE VILLE CLASSIQUE PROVENANT DE LA HOUILLE

Par G. COMBET
(Directeur Général du Gaz de France (Service National))

et A. BOLZINGER
(Directeur Technique du Gaz de France (Service National))

COMITÉ NATIONAL FRANÇAIS

INTRODUCTION

1.º — Après avoir, à l'origine, distribué du gaz de houille, l'industrie gazière y a assez rapidement ajouté le gaz à l'eau, enrichi de gaz d'huile, mais tous ces mélanges restaient utilisables dans les brûleurs en service.

L'apparition du gaz naturel, constitué surtout de méthane, puis de gaz comme le propane et le butane, ayant des caractéristiques de combustion très différentes des gaz précédemment distribués, a montré qu'on ne pouvait dans un brûleur fait pour un gaz déterminé, utiliser n'importe quel autre gaz. Cette servitude est encore plus rigoureuse pour certaines applications industrielles que pour les brûleurs domestiques.

Ces considérations ont entraîné dans la plupart des pays des études sur la substitution possible des différents gaz les uns aux autres. Les études françaises sur cette question, sont résumées dans différents travaux (1).

Selon ces études, un gaz est caractérisé sur un diagramme par un

[illegible] de Wobbe $\frac{P}{\sqrt{d}}$

P étant son pouvoir calorifique en kcal/m³N (*)
d sa densité par rapport à l'air,

et l'abscisse, le potentiel de combustion Delbourg $C = \frac{E}{\sqrt{d}}$

où $E = H^2 + 0{,}6\ CO + 0{,}6\ C_nH_m + 0{,}3\ CH^4$

et H^2, CO, C_nH_m, CH^4 représentent les proportions volumétriques de ces différents gaz, pour 100 volumes de gaz.

Il a été montré qu'un gaz pouvait être substitué à un autre dans un brûleur établi pour ce dernier, si leurs points figuratifs se trouvaient dans une même zone du diagramme, l'étendue de cette zone étant une caractéristique du brûleur en question et de son réglage.

Ceci étant, on peut considérer que les gaz ou mélanges de gaz susceptibles d'être distribués par l'industrie gazière, se groupent en trois grandes familles:

- les gaz de pouvoir calorifique usuels de l'ordre de 4 à 5000 kcal/m³N, dont le prototype est le gaz des usines classiques produisant le gaz de houille comme gaz de base.
- les gaz riches à pouvoir calorifique de 9-10.000 kcal/m³N, dont le prototype est le gaz naturel, (gaz d'huile riches de remplacement, mélanges air-propane de même pouvoir calorifique).
- les gaz très riches, comme le propane et le butane.

A ces trois familles correspondent en France des brûleurs normalisés pour les appareils domestiques. Ces brûleurs ont des caractéristiques assez profondément différentes pour qu'il ait été nécessaire de concevoir dans l'état actuel des choses, ces trois types de brûleurs différents. A chacun d'eux correspond sur le diagramme dont il vient d'être question une zone d'interchangeabilité (Figure 1). Tous les gaz dont les points figuratifs sont dans une de ces zones, sont utilisables sans réglage dans un brûleur établi et réglé pour un de ces gaz. Si l'on admet que l'on fera avant la substitution un réglage de l'admission d'air, chaque zone se trouve un peu plus étendue, mais de toutes façons, les trois zones en question restent très éloignées les unes des autres sur le diagramme et on conçoit donc qu'on n'ait pu encore établir le brûleur "tous gaz" auquel on travaille, et qu'on ait dû par conséquent recourir à trois types différents.

2° — Actuellement, en France, comme d'ailleurs en beaucoup d'autres pays, la plus grande partie du gaz de ville provient de la houille

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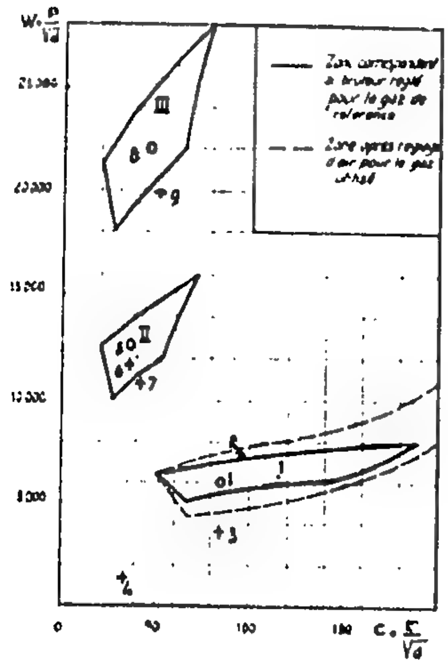
(*) le m³N ou m³ normal est mesuré à 0° 760 mm et sec

sous forme principalement de mélanges de gaz de houille, de gaz à l'eau [illegible] nent à la première famille dont il est question plus haut.

On utilise le gaz naturel (gaz de la 2e famille) dans la Région du Sud-Ouest seulement

Le propane (gaz de la 3e famille) est utilisé dans de petites exploitations dont le nombre grandit, mais dont le peu d'importance fait que ce gaz ne représente qu'une faible proportion de l'ensemble.

Fig 1. ZONES D'INTERCHANGEABILITÉ CORRESPONDANT AUX BRÛLEURS FRANÇAIS



I. [illegible] (Blue water Gas) 4 Gas pauvre de gazogène [illegible])
II. [illegible] 5 Gaz naturel [illegible] 6 Air et Propane 7 Gaz [illegible]
III. 3me [illegible] (Brûleurs pour Propane) 8 Butane 9 Propane

En 1951, par exemple, la puissance calorifique des gaz distribués [illegible] classiques, 1,53%, du gaz naturel, 0,07% du propane.

Bien que les gaz de la 2e famille soient susceptibles de s'augmenter de gaz résiduaires provenant de raffineries de pétrole, et ceux de la 3e famille de se développer, les gaz de la première famille resteront encore prépondérants dans le proche avenir.

Ce sont donc les gaz de la 1ere famille qui intéressent, au premier chef, l'industrie du gaz française.

Or, si jusqu'ici, la matière première de base de la production de ces gaz a été la houille, il devient opportun de faire appel à d'autres matières premières telles que les dérivés des pétroles.

D'une part, des gaz résiduaires non condensables et condensables deviennent disponibles dans les raffineries de pétrole; d'autre part, de grandes quantités d'huiles lourdes de pétrole, résidus de distillation et de cracking des huiles brutes, apparaissent sur le marché à des prix avantageux.

Si les gaz non condensables et condensables provenant des raffineries, appartenant aux 2e et 3e familles, peuvent souvent être utilisés en l'état en remplaçant les appareils d'utilisation anciens par des appareils ayant des brûleurs appropriés, il n'en est pas toujours ainsi, soit parce qu'on estime cette opération trop coûteuse, soit parce qu'ils ne peuvent fournir qu'un appoint dans une exploitation distribuant un gaz de la première famille.

On est donc conduit à traiter ces gaz pour leur donner une composition leur permettant, soit de remplacer le gaz de ville classique, soit d'en être suffisamment proche pour permettre un appoint important sans sortir, pour le mélange, des limites d'interchangeabilité.

Lorsqu'il s'agit d'autre part de gazéifier des huiles lourdes, le gaz produit doit aussi, pour les mêmes raisons, avoir une composition le rendant parfois absolument semblable, parfois seulement assez proche du gaz préalablement distribué.

On a donc fait en France ces dernières années, un certain nombre de recherches et de réalisations ayant ces objectifs en vue, et le présent rapport se propose d'en rendre compte, c'est-à-dire d'exposer ce qui a été fait dans le but d'obtenir, en partant des dérivés du pétrole (gaz non condensables, condensables ou huiles) des gaz substituables aux mélanges à base de gaz de houille généralement distribués par les usines à gaz classiques.

Nous pensons que ce travail intéresse les pays, probablement assez nombreux, qui sont dans le même cas que la France, et en particulier, ceux qui, devant renouveler leur matériel ou faire face à un important développement de l'industrie du gaz, peuvent faire appel plus facilement à des techniques nouvelles.

CARACTÉRISTIQUES TECHNIQUES DU PROBLÈME

Caractéristiques des gaz distribués par les usines à gaz classiques

Les usines à gaz classiques distribuent des mélanges de gaz de houille, de gaz à l'eau et de gaz de gazogène caractérisés par une *teneur en Hydrogène élevée* (de l'ordre de 10 à 50%) et dont le pouvoir calorifique (1200 kcal/m³N généralement en France) exige une *proportion très appréciable d'hydrocarbures riches* comme le méthane (environ 20%).

Voici par exemple les caractéristiques d'un gaz moyen distribué en France:

CO^2	3,7%	Pouvoir calorifique supérieur 1200 kcal/m³N
C_nH_m	2,7%	Densité 0,52
O^2	0,6%	Indice de Wobbe: $W = \dfrac{P}{\sqrt{d}} = 5800$
CO	15 %	
H^2	45,2%	
CH^4	18,9%	
N^2	13,9%	Potentiel Delbourg (*) $C = \dfrac{E}{\sqrt{d}} = 85$

Ces gaz doivent contenir *peu de CO^2* (moins de 5%), une quantité de CO limitée et être débarrassés de diverses impuretés par un traitement approprié.

Si la nécessité d'une teneur élevée en hydrogène de ces gaz, en fait ressembler la production à celle des gaz de synthèse, elle en diffère toutefois très sensiblement par la nécessité de conserver une proportion importante d'hydrocarbures riches et limiter au contraire celle de CO^2.

Problème du Carbone.

Pour tirer d'un hydrocarbure un gaz contenant une telle proportion d'hydrogène libre, on dissocie partiellement l'association carbone-hydrogène qu'il constitue, par action de la chaleur, éventuellement en présence de vapeur d'eau et d'oxygène (pur ou emprunté à l'air).

Or les hydrocarbures à traiter dont le rapport carbone/hydrogène, va de 3 pour le méthane, à 8,5 pour les huiles lourdes, résidus de cracking des raffineries de pétrole, sont beaucoup plus riches en carbone que le gaz désiré.

(*) Voir dans l'Introduction, la définition du "potentiel Delbourg".

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Il est clair que seule l'action de la vapeur d'eau peut apporter de l'hydrogène [illegible] dans l'hydrocarbure traité. Par suite, à défaut d'une action *efficace* et *massive* de la vapeur d'eau, la gazéification projetée laissera un résidu de carbone, soit sous forme de dépôt carboneux sur la masse de contact qui devra être regénérée, soit sous forme de corps riches en carbone constituant les goudrons ou entraînés par le gaz à l'état solide (noir de fumée) ou gazeux (naphtaline et hydrocarbures divers).

Importance de la catalyse.

Il apparait essentiel de pouvoir conduire l'ensemble des réactions de gazéification, tant pour assurer *l'action suffisante de la vapeur d'eau* que pour orienter la décomposition qui doit *laisser subsister des produits riches*, donnant au gaz son pouvoir calorifique, et *éviter également la formation de sous-produits gênants*. On a généralement, jusqu'ici, realisé ces gazéificantions, soit dans un espace vide, soit sur des empilages réfractaires, et il ne semble pas qu'on ait encore tiré de la catalyse tout le parti possible.

Dans ce qui suit, on verra par exemple comment dans une réalisation française, son emploi a permis d'éviter, au cours de la gazéification d'huiles lourdes, le dépôt dans le barillet-laveur de grandes quantités de carbone, difficilement utilisables.

Elle parait en tous cas, devoir jouer un rôle essentiel et encore peu exploré.

Chaleur de réaction mise en jeu.

Dans les réactions de gazéification, seule l'action de l'oxygène dégage de la chaleur, les autres réactions étant en général fortement endothermiques. Suivant la part relative des réactions exothermiques et endothermiques, la gazéification sera

autothermique s'il n'y a pas de chaleur à fournir, ce qui exigera forcément de l'oxygène

ou *endothermique* dans le cas contraire.

Les avantages des opérations autothermiques continues sont tels, qu'on doit d'abord se demander s'il est possible d'obtenir ainsi un gaz suffisamment proche du gaz désiré, ou en tous cas rechercher les possibilités de telles opérations.

En dépit de la complexité du problème théorique, son étude approchée permet d'avoir une idée de ce qui est possible et de ce qui ne l'est pas.

Une caractéristique essentielle du gaz à obtenir étant une teneur en hydrogène suffisante, on peut chercher à savoir celle qui peut être atteinte théoriquement et en supposant qu'on peut conduire à volonté les différentes réactions.

Elle sera d'autant plus basse:

... C/H du produit de départ est plus élevé.

— que la chaleur que l'on consent à fournir à la réaction sera faible (chaleur nulle pour une réaction autothermique).

— que le pouvoir calorifique du gaz exigé sera élevé.

— que la quantité de carbone dont on accepte le dépôt est faible.

Plusieurs conséquences en résultent.

En premier lieu, lorsqu'il s'agit de "réformer" un hydrocarbure gazeux (methane, propane, butane par exemple) on peut atteindre, toutes choses égales d'ailleurs, des teneurs en hydrogène beaucoup plus élevées qu'avec des huiles, parce que le rapport C/H de ces gaz est faible et qu'ensuite le pouvoir calorifique du gaz réformé peut être bas, puisqu'on peut ensuite facilement le rétablir par addition d'une certaine quantité du gaz primitif.

En second lieu, la quantité de carbone dont on peut accepter le dépôt, dépend étroitement du procédé de gazéification employé. Si le procédé est continu, aucun dépôt appréciable de carbone n'est acceptable sur la masse de contact. Si le procédé est discontinu, comportant un cycle constitué d'un temps de chauffage et de régénération de la masse de contact et d'un temps de gazéification, le dépôt sur la masse de contact d'une quantité appréciable de carbone est acceptable, puisqu'elle peut être brûlée dans le premier temps.

Un tel procédé permettra donc, toutes choses égales d'ailleurs, d'obtenir des teneurs en hydrogène plus élevées.

Ces observations peuvent être complétées par les ordres de grandeur suivants:

Avec un hydrocarbure gazeux comme le propane et les facilités qu'on a en ce qui concerne le pouvoir calorifique:

— le craquage autothermique par air-vapeur doit permettre d'atteindre sans dépôt de carbone, des teneurs en hydrogène de l'ordre de 30%, le pouvoir calorifique étant toutefois assez bas (de l'ordre de 1600 kcal/m^3).

Il n'est pas douteux qu'en remplaçant l'air par de l'oxygène pur, on devrait pouvoir atteindre 50% d'Hydrogène.

— le craquage à la vapeur seule, avec un apport de chaleur d'un millier de Kcalories par kg de propane, doit permettre d'obtenir plus de 50% d'hydrogène, le pouvoir calorifique étant cependant inférieur à 3000 kcal/m^3.

Mais, avec une huile, et la nécessité *d'obtenir directement un gaz à* 4200 kcal/m^3, il en va tout autrement.

— un craquage autothermique avec oxygène pur ne semble pas pouvoir permettre de dépasser 25% d'hydrogène sans dépôt de carbone, et 35% si on accepte un dépôt de carbone atteignant 30% du poids d'huile gazéifiée.

— un apport de chaleur de l'ordre de 1200 kcal par kg d'huile porterait [illegible] entes à 30 et 15 % environ.

— quant au craquage autothermique à l'air, il ne peut donner qu'un gaz de gazogène de pouvoir calorifique assez bas (1000 kcal/m^3), et non d'ailleurs sans libération de carbone, s'il s'agit d'huiles riches en carbone.

Les opérations autothermiques ont donc des possibilités très limitées dans le cas de la gazéification d'huiles lourdes, et même l'emploi d'oxygène pur, d'ailleurs coûteux autrement qu'à très grande échelle, ne peut donner que des solutions très partielles du problème.

Par conséquent, la plupart des opérations envisagées, exigera généralement *un apport important de chaleur*, qui dépend évidemment de différentes données, mais dont l'ordre de grandeur est le millier de kcalories par kg de matière première traitée.

En résumé:

La production de gaz de la première famille dont il est question, est caractérisée par:

— l'excès de carbone des dérivés du pétrole par rapport au gaz final désiré.

— le rôle essentiel que doit être appelée à jouer la catalyse.

— les apports de chaleur importants généralement nécessaires.

2ème Partie

RECHERCHES ET RÉALISATIONS FRANÇAISES (CONCERNANT LA PRODUCTION, A PARTIR DES DÉRIVÉS DU PÉTROLE, DE GAZ ANALOGUES AU GAZ DE VILLE CLASSIQUE)

Les apports de chaleur nécessaires pour certaines réactions, et les moyens employés pour réaliser ces apports sont à la base de la conception des appareils de gazéification et de leurs propriétés. Aussi est-ce sur cette caractéristique qu'on peut le mieux baser leur classification.

I — PROCÉDÉS AUTOTHERMIQUES

Nous mentionnerons dans cette revue, en raison de leur intérêt, un certain nombre de procédés autothermiques utilisés en France, bien qu'ils ne permettent pas comme on l'a montré, d'obtenir le gaz de ville répondant exactement aux qualités indiquées.

A — GAZÉIFICATION A L'AIR-VAPEUR

1 — *Combustibles gazeux*

On a réalisé en France le "reforming" autothermique du gaz naturel (méthane) et du propane à l'air, ou à l'air et vapeur (2).

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Un mélange d'air et de méthane ou propane dans les proportions voulues, est injecté dans une masse de contact constituée par des grains d'alumine ou d'alumine au nickel (pour le gaz naturel 2,5 %). Le gaz réformé obtenu a par exemple avec le propane, sans vapeur, une composition telle que: CO^2 : 3% – CO : 19% – H^2 : 21% – CH^4 : 1% – N^2 : 50%.

Le pouvoir calorifique supérieur est de 1600 kcal/m³N, et on enrichit ce gaz par addition de propane pur. La teneur en hydrogène peut être portée à près de 30% par la surchauffe de l'air et l'emploi de la vapeur.

Ces procédés extrêmement simples et peu coûteux, donnent un gaz qui, sans être substituable parfaitement au gaz de ville, est à la limite d'utilisation dans la plupart des brûleurs français destinés à ces gaz, après un réglage d'air.

Aussi ces procédés, avec le propane, ont été utilisés dans des exploitations dont on ne voulait pas remplacer les appareils d'utilisation, et plus encore pour produire un gaz de pointe. Sa teneur en hydrogène relativement élevée permet en effet d'en ajouter une très forte proportion au gaz de ville (mélange pour moitié de chacun des deux gaz).

2 – Gasoil – Gazogène GEIM (*)

Le gazogène GEIM est une réalisation en France du procédé Dayton-Faber.

Il a été placé d'abord en France comme moyen de production de petites usines, vers la fin de la dernière guerre (3).

Il ne produit qu'un gaz qui a bien le pouvoir calorifique nécessaire (par exemple 1200 kcal m³N), mais ne contient que très peu d'hydrogène (5 à 6%). Aussi des difficultés d'utilisation se sont immédiatement produites. Quelques tentatives d'améliorations par préchauffage de l'air et de la vapeur n'ont donné que 4 ou 5 points d'hydrogène (3).

3 – Gazogène à fuel-oil et à goudron OCCR (**)

Cet appareil mis au point récemment, est en service pour le chauffage des fours d'une usine du Gaz de France (4)

Il ne prétend naturellement que faire du gaz de gazogène, mais peut utiliser du goudron lorsqu'il arrive que celui-ci se vend mal, ou lorsqu'il est d'une qualité défectueuse.

Le combustible est entraîné par des injections d'air tangentielles dans un cylindre vertical et se trouve partiellement gazéifié.

(*) Gaz à l'eau et Industriels de Montrouge

(**) Office Central de Chauffe Rationnelle

Le gaz produit est un gaz de gazogène dont le pouvoir calorifique [illegible] kcal/m^{3}N.

Sa température est élevée à la sortie de l'appareil (1250°C), de sorte que beaucoup de la chaleur des gaz est à l'état "sensible".

D'autre part, le carbone, malgré la turbulence vive entretenue dans l'appareil, est incomplètement gazéifié et le gaz en contient en suspension environ 0,400 kg/kg de fuel gazéifié,

et 0,500 kg/kg de goudron gazéifié.

Ce carbone brûle d'ailleurs dans les fours à chauffer.

Le rendement thermique, compte tenu de la chaleur sensible du gaz et de la chaleur fournie par le carbone en suspension, est élevé (de l'ordre de 95%), mais si le gaz était refroidi et débarrassé de son carbone on n'y retrouverait plus que 45 à 50% de la chaleur du combustible initial).

Cela limite donc l'utilisation de ce gazogène qu'on peut cependant espérer améliorer

II — GAZÉIFICATION À L'OXYGÈNE PUR ET VAPEUR

Un essai récent, (juillet 1953), a été effectué en France pour gazéifier du fuel-oil lourd avec de l'oxygène et de la vapeur, afin d'obtenir directement par procédé autothermique, un gaz de ville à 4200 kcal/m^3, ayant une teneur élevée en hydrogène.

Cet essai a été fait sur un appareil pilote de la PANINDCO (Cie Pan Européenne d'Installations et d'Équipements Industriels) de sa station d'essais de ROUEN

Cet appareil est normalement destiné à gazéifier des fines de charbon entraînées en suspension. Le combustible est injecté avec de l'oxygène et de la vapeur, fortement préchauffés dans des "Cowpers", en haut d'une chambre verticale et s'y gazéifie.

Malgré un préchauffage important de l'oxygène et de la vapeur, la gazéification de fuel-oil dans les conditions désirées n'a pu être réalisée convenablement dans ces premiers essais (Forte proportion de carbone non gazéifié, et pouvoir calorifique du gaz insuffisant).

Ceci confirme les considérations techniques qui précèdent, mais ces essais sont insuffisants pour que ces conclusions soient définitives.

II — PROCÉDÉS ENDOTHERMIQUES

A — PRÉCHAUFFAGE DES FLUIDES INJECTÉS

La chaleur nécessaire, la température de réaction et la quantité de fluides injectés, sont telles que leur surchauffe ne peut donner, en dehors d'une amélioration du bilan thermique par récupération, que des résultats très limités. On en a mentionné plus haut les quelques applications.

Il n'est d'ailleurs souvent pas possible de préchauffer au-dessus de 3/400° C [illegible]tes, sans avoir une combustion prématurée avec formation abondante de noir de fumée.

B — APPORT DE CHALEUR PAR CHAUFFE EXTERNE

Le chauffage du réacteur par ses parois, permet la réalisation d'une opération continue, mais qui exige de ce fait la gazéification continue, principalement par la vapeur, du carbone déposé sur la masse de contact, et par suite une température de l'ordre de 900° C au moins et un apport particulièrement élevé de chaleur.

La nature de la paroi limite la température du chauffage.

La surface de chauffage d'une capacité, cylindrique par exemple augmentant par ailleurs beaucoup moins vite que son volume, la quantité de chaleur nécessaire ne pourra être apportée que si ces capacités sont de petit diamètre.

On doit donc utiliser, soit de nombreux tubes de petit diamètre chauffés dans un four, soit un gros réacteur chauffé par des tubes de fumées.

La réforme du gaz naturel, voire du propane et du butane en présence de vapeur et éventuellement d'un peu d'air, est d'utilisation courante.

On pratique en France:

— la réforme du gaz naturel et propane (procédé Hercules Powder (5) utilisant comme réacteurs des tubes en acier spécial et procédé Starck, en montage.

— la réforme de gaz de raffinerie (procédé Gas Machinery Co. utilisant des tubes en carborundum, en montage).

En ce qui concerne la gazéification des huiles lourdes, le problème est infiniment plus difficile.

Le dépôt de carbone sera plus élevé et difficile à éliminer, et le pouvoir calorifique suffisant doit être directement obtenu. Les considérations techniques de la première partie en ont fait ressortir les conséquences.

Ce procédé est cependant à l'étude au Gaz de France, parce qu'il paraît se prêter à des solutions relativement simples pour des appareils produisant 10 à 20.000 m³/jour.

Dans cet ordre d'idées, il faut signaler l'utilisation assez générale faite par les usines à gaz françaises à la fin de la dernière guerre, du craquage de gas-oil dans les fours d'usines à gaz de tous types (6), et même une réalisation de petits fours de fortune en matériaux réfractaires (7).

Le but de ces opérations était de pallier le manque de charbon et d'augmenter la puissance de production des fours, la production d'une calorie-gaz de gas-oil exigeant moins de chauffage que celle d'une calorie-gaz classique.

[illegible] produit que des gaz d'huiles riches (8600 kcal/m³) à faible teneur en hydrogène (20 à 25%) et les inconvénients probables de ces fabrications passaient inaperçus dans la fabrication d'ensemble.

C — APPORT DE CHALEUR PAR CHAUFFAGE ÉLECTRIQUE

En raison du prix de la calorie-électrique, ce procédé ne paraît guère pouvoir être utilisé que partiellement — Nous n'avons en tous cas rien effectué, ni projeté de précis en ce sens.

D — PROCÉDÉS À MARCHE CYCLIQUE
(ONIA-GEGI à l'Usine à Gaz de CAHORS) (*)

Dans ce type d'appareils, à marche discontinue, la masse de contact est à la fois chauffée et regénérée dans le premier temps, et la gazéification s'effectue dans un second temps grâce à la chaleur ainsi accumulée.

Le dépôt de carbone peut donc être accepté sur la masse de contact, et il en résulte des possibilités dont on a fait ressortir l'intérêt dans la première partie. Le chauffage de la masse est direct et facile.

Ce système, très familier à l'industrie du gaz (pour la production de gaz à l'eau) exige cependant des vannes et des commandes automatiques pour réaliser les changements de marche du cycle, et des appareils suffisamment volumineux pour que la durée du cycle ne soit pas excessivement courte. Ces installations sont donc relativement coûteuses.

Le procédé ONIA-GEGI qui vient d'être mis au point en France, gazéifie du fuel lourd, il peut aussi servir à la réforme d'hydrocarbures gazeux (**) et constituer un appareil mixte susceptible, en cas de défection de ceux-ci, de reprendre la gazéification d'huile.

On comprendra mieux ce que le procédé apporte de nouveau en retraçant sommairement l'évolution des procédés cycliques de gazéification d'huile. Celle-ci a été pratiquée depuis fort longtemps sur des empilages refractaires, pour produire à l'origine un gaz à peu près semblable aux gaz de houille ou gaz à l'eau carburé distribués. Il fallait pour cela un craquage très poussé de l'huile qui entrainait un dépôt abondant de matières carboneuses sur les empilages, difficile à brûler lorsqu'il s'agit d'huiles lourdes, et une récupération de quantités considérables (250

(*) ONIA-GEGI — Office National de l'Industrie de l'Azote et Gaz à l'Eau et Gaz Industriels de Montrouge (Il s'agit de la même Société qui a réalisé le gazogène GEIM cité plus haut — l'ONIA s'intéresse à ce problème pour fabriquer du gaz de synthèse.

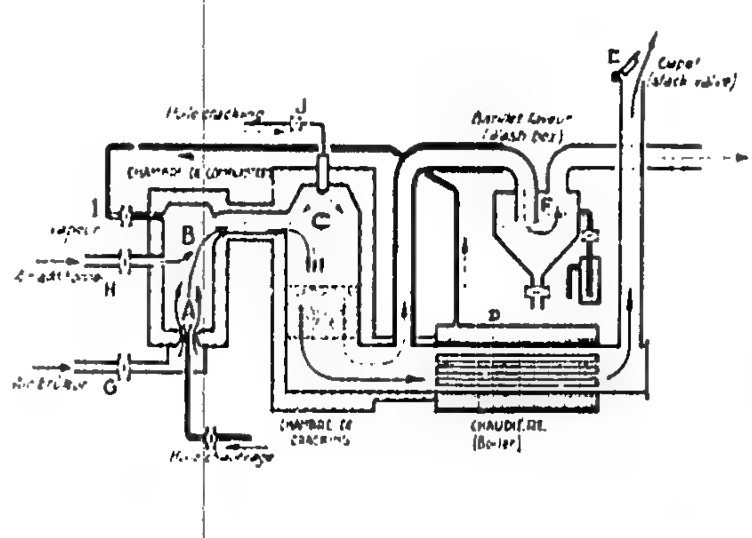
(**) Aux U.S.A., U.G.I., à l'Usine à Gaz de Philadelphie, utilise un procédé cyclique pour réformer le gaz naturel.

[illegible] de gaz) de matières carboneuses solides dans le barillet-laveur, matières dont on avait ensuite difficilement l'utilisation. Le goudron était épais et les installations de traitement du gaz assez importantes.

Ces inconvénients paraissent avoir été très sérieux, si on en juge par les préoccupations des inventeurs de l'époque.

Cette situation s'est complètement modifiée aux U.S.A. depuis que le gaz d'huile n'est plus qu'un appoint du gaz naturel, au lieu d'être celui du gaz de houille. Pour produire un gaz à 9500 kcal/m³ à faible

Fig. 2 - Procédé ONIA.GEGI
(Cracking cyclique d'huile)



1er temps - Chauffage (Clapet E ouvert, ainsi que AGH)
2me temps - Production (clapet E fermé, I J ouverts)

teneur en hydrogène, un craquage peu poussé est suffisant et le carbone solide invendable a disparu des barillets-laveurs, les dépôts sur les empilages sont par ailleurs plus réactifs.

Enfin, Ed. L. HALL a réussi à brûler sur les empilages les dépôts provoqués par les huiles les plus lourdes, en surchauffant l'air de combustion (générateurs Hall à 1 ou 2 corps - procédé du "back blast" (3)

Malheureusement, pour la plupart des régions françaises, c'est toujours un gaz de ville classique qu'il faut produire.

Le problème restait donc entier et il semble avoir été convenablement résolu par le remplacement des empilages réfractaires par un catalyseur approprié en vrac. A cela, s'est ajouté un gros effort de simplification de l'installation qui ne comporte que des organes simples et robustes.

Fonctionnement:

La figure 2 représente un schéma du générateur et de son fonctionnement (9).

1er *temps*: chauffage et régénération du catalyseur en C — (Brûleur A, air de combustion G, air additionnel H et clapet E ouverts).

2ème *temps*, production (brûleur A, air G et H, clapet E fermés). L'huile est pulvérisée en J sur le catalyseur C, en présence de vapeur injectée en I où elle se surchauffe légèrement — Le gaz produit, ne rencontrant pas d'autre issue, passe par le barillet laveur.

Ces manoeuvres, très simples, sont commandées automatiquement. La fermeture du clapet E se fait avec un léger retard, pour permettre l'évacuation des fumées produites pendant le temps précédent. La pulvérisation de fuel-oil en G est arrêtée un peu en avance, la vapeur continuant à produire du gaz à l'eau.

Résultats obtenus — Traitement du gaz:

Le procédé a permis d'obtenir avec du fuel lourd (*), suivant les conditions de marche, des gaz très divers, d'un pouvoir calorifique allant de 3000 à 10 000 kcal/m³N et d'une teneur en hydrogène de 50 à 25%.

Voici d'ailleurs les résultats concernant la production de gaz à 4200 kcal/m³N effectuée depuis le début de 1953, pour fournir la totalité du gaz distribué par l'Usine à Gaz de Cahors (soit de l'ordre de 6 à 8.000 m³/jour).

Composition du gaz *final*:				
	CO^2	5,6%	CO	23,6%
	C_nH_n	3,2%	H^2	47,2%
	O^2	0,8%	CH^4	13 %
			N^2	6,6%

(*) *Fuel lourd utilisé*

Densité	0,96	Pouvoir calorifique supérieur	10 250 kcal/kg
Viscosité Engler à 50°	31,5	Distillation début	200°
Résidu Conradson	9,4 %	5 % à	291°
Soufre	1 %	10 % à	337°
		Décomposition à	361°

Pouvoir calorifique supérieur kcal/m³N: *4200* Densité: 0,52

— Impuretés : gr/m³N

	avant traitement	*gaz final*
goudron et carbone libre	75/80	moins de 0,01
H_2S	15/50	satisfait au règlement
Soufre organique	0,15/0,6	0,35/0,4
Benzol	45/55	25
Naphtaline	6/7	0,07

— Consommations par m³N

fuel-oil lourd:	craquage kg	0,563
	chauffage kg	0,118
		0,701

L'installation produit sa vapeur (45 à 60 kg m³N) et la consommation d'électricité est de 0,19 kWh m³N

— Produits récupérés : (kg/m³N)

goudron anhydre (*)	0,076
naphtaline	0,0063
benzol	0,026

Les opérations de traitement restent assez nombreuses pour une usine peu importante

Après quelques tâtonnements, on a adopté le traitement suivant: Le gaz, à 60/80° C dans le barillet-laveur, est réchauffé à 85/90° C puis passe au dégoudronneur électrostatique, de façon à y déposer du goudron, sans eau.

Le gaz, saturé de naphtaline à 15° C., est ensuite refroidi par arrosage direct dans des scrubbers vides, de sorte que la naphtaline condensée est entraînée par l'eau et récupérée.

Un débenzolage partiel au charbon actif, arrête le benzol en excès pour la tenue des joints de caoutchouc des canalisations de ville, la naphtaline, et une partie appréciable du soufre organique.

Une épuration classique à l'oxyde de fer complète le traitement.

Discussion des résultats:

On obtient un gaz dont la similitude avec le gaz de ville classique est très satisfaisante

(*) Le goudron, après décantation, contient 5 à 7% d'eau, 8 à 13% de naphtaline, 8 à 9% de carbone libre

— L'action du catalyseur se traduit d'abord par un goudron de qualité [illegible] ntage même de l'appareil, et surtout par la disparition au barillet-laveur du carbone solide, sousproduit dont on n'aurait su que faire. Au lieu de 300 gr/m³N de ce produit, ce qui est énorme, il est infiniment plus facile de se débarrasser de 3 gr/m³N de naphtaline.

— La catalyse d'autre part a une action très importante bien que moins apparente.

L'étude du gaz obtenu montre qu'il est constitué d'une forte proportion de gaz à l'eau (61,6 %), d'assez peu d'un gaz de craquage assez riche à 8300 kcal/m³N (30,2 %) et de fumée (8,2 %).

Les anciens appareils de gazéification d'huile sur empilages fournissaient un gaz constitué d'une plus forte proportion d'un gaz de craquage à 7400 kcal/m³N seulement (gaz à l'eau 35 %, gaz de craquage 58 %, fumées 7 %).

Le catalyseur aurait donc ralenti le craquage et favorisé la gazéification du carbone par la vapeur.

Au point de vue pratique, il s'ensuit que le procédé semble particulièrement adapté aux huiles à forte teneur en carbone et médiocres pour le craquage, donc aux résidus les moins estimés.

La catalyse paraît donc avoir fourni des résultats appréciables et conférer au procédé son originalité.

Le prix d'établissement de l'installation et la complexité du traitement du gaz ne permettent pas de la conseiller pour les toutes petites usines; nous pensons, sauf cas particuliers, qu'il doit être réservé à des productions supérieures à 20 000 m³/jour.

E. — LITS MOUVANTS

Dans ces procédés, la masse de contact circule entre un réchauffeur-régénérateur, où elle est chauffée et éventuellement régénérée, et le réacteur où l'huile est gazéifiée, grâce à la chaleur apportée par la masse de contact. Celle-ci se présente, soit sous forme de billes ("Thermofor Catalytic Cracking" de l'Industrie du Pétrole) soit sous forme de fines particules fluidisées ("Fluid Catalytic Cracking").

La régénération de la masse de contact s'effectue comme dans les procédés cycliques, à cette différence près que les opérations s'effectuent successivement dans l'espace, au lieu de s'effectuer successivement dans le temps.

Le fonctionnement est continu, donc ne nécessite ni appareils de changements de marche plus ou moins automatiques, ni appareils trop volumineux. De grandes productions sont donc possibles par appareil.

Par contre, la séparation des enceintes entre lesquelles circule la masse de contact exige un équilibre parfait des pressions et une régulation appropriée et précise. Le coût de cette régulation d'une part, les pertes

de chaleur, probablement élevées dans la circulation de la matière et [illegible] installations sont moins importantes, risquent de rendre ces procédés inapplicables à de petites productions; mais ce n'est pas certain.

Il faut enfin éviter toute agglomération de la masse de contact, surtout lorsqu'elle est fluidisée, par des produits carboneux déposés par l'huile, et cela paraît devoir poser des problèmes difficiles.

L'utilisation de ces procédés à la production de gaz d'huile, n'a pas dépassé au Gaz de France, le stade des essais de laboratoire et des études consécutives d'installations pilotes.

Il est cependant probable que l'un de ces procédés sera prochainement essayé à l'échelle d'une installation pilote

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Résumé

Le gaz de ville distribué en France reste, pour une très large part, un gaz constitué par un mélange de gaz de houille et de gaz à l'eau.

Cependant, on tend de plus en plus à utiliser dans sa fabrication des résidus gazeux ou liquides des raffineries de pétrole. Ceux-ci n'ayant cependant le plus souvent qu'un rôle d'appoint, le problème consiste à en tirer un gaz assez semblable au gaz de ville classique, riche en hydrogène.

Ce problème est caractérisé :

- par le fait que les produits de départ contiennent beaucoup plus de carbone que le gaz désiré ;
- par l'intérêt de la catalyse pour conduire convenablement certaines opérations ;
- par le fait que ces opérations exigent généralement un apport important de chaleur.

Tenant compte de ces considérations techniques et de leurs conséquences sur les possibilités d'obtenir certains résultats, une revue des recherches et réalisations françaises dans les différentes voies possibles est présentée :

- Craquage autothermique d'hydrocarbures gazeux et d'huiles (Procédés Gaz de France, Gazogènes G.I.M. et O.C.G.R.)
- Procédés avec apport de chaleur : (chauffage externe — Procédé cyclique ONIA-GEGI de gazéification d'huile employant un catalyseur spécial qui a permis d'obtenir un gaz substituable au gaz de houille, en évitant les dépôts et résidus invendables de carbone — Techniques Thermofor et Fluidisation).

Ces études paraissent devoir intéresser les pays qui ont à résoudre des problèmes semblables, et ceux dans lesquels le développement de l'Industrie du Gaz ou le renouvellement de ses installations, fait envisager le recours à des techniques nouvelles de production.

SUMMARY

The town gas distributed in France is still a gas composed of a mixture of coal gas and water gas.

However, it is becoming more and more customary to utilize in its manufacture gaseous or liquid residues from oil refineries. These residues generally play only a contributive part: the problem therefore consists in the production of a gas more or less similar to the classical town gas, rich in hydrogen.

This problem is characterised:

— by the fact that the products used at the start contain much more carbon than the gas which is needed;

— by the interesting use of catalysis in the suitable handling of certain operations;

— by the fact that these operations generally require an important addition of heat.

Taking into account these technical considerations and their consequences in obtaining certain results, a survey of French researches and realizations in the different possible methods is presented:

— Autothermal cracking of gazeous hydrocarbons and oils (Gaz de France processes, gasgenerators by GEIM and OCCR).

— Processes requiring the addition of heat: (External heating — Cyclic process by ONIA GEGI of oil gasification utilizing a special catalyst which has allowed the production of a gas which can be conveniently substituted for coal gas, while avoiding unsaleble carbon deposits and residues. Thermofor cracking and Fluid phase cracking).

These studies seem to be of some interest for countries which have similar problems to solve, and to others in which the expansion of the Gas industry in the renewal of its plants suggests the consideration of and resort to new technical means of production.

RESUMO

O gás urbano distribuído na França é, ainda, em grande parte, um gás constituído pela mistura de gás de hulha e gás d'água.

Tende-se todavia e cada vez mais a empregar na sua fabricação resíduos gasosos ou líquidos das refinarias de petróleo. Como, porém, êstes resíduos, em geral, desempenham apenas papel de contribuição, o problema consiste em obter dêles um gás mais ou menos semelhante ao clássico gás urbano, rico em hidrogênio.

Esse problema é caracterizado:

— pelo fato de as matérias primas iniciais conterem muito mais carbono do que o gás desejado;

— pelo interêsse da catálise na condução adequada de certas operações;

— pelo fato de essas operações exigirem, geralmente, importante quantidade de calor.

Levando em conta essas considerações técnicas e suas consequências sôbre as possibilidades de se obterem certos resultados, é apresentado um exame das pesquisas e realizações francesas nos diferentes domínios possíveis:

— Processo de "cracking" autotérmico de hidrocarbonetos gasosos e de óleos (Processos Gás de França, gasogênios GEIM e OCCR).

— Processos com consumo de calor (aquecimento externo; Processo cíclico ONIA-GECI de gaseificação de óleo empregando um catalizador especial que permitiu obter-se um gás sucedâneo do gás de hulha, evitando-se os depósitos e resíduos não vendáveis de carbono; "cracking" Thermofor e de Fluidização).

Êsses estudos parecem dever interessar aos países que precisam de resolver problemas semelhantes, e aquêles onde o desenvolvimento da indústria do gás, ou a renovação de suas instalações, indica o recurso a novas técnicas de produção.

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CHERADAME (R.)
França

PROGRÈS DANS L'UTILISATION DES CHARBONS EN FRANCE

Par R. CHERADAME

COMITÉ NATIONAL FRANÇAIS

L'utilisation des charbons français a fait l'objet de 2 communications à la IVème Conférence Mondiale de l'Energie: l'une sur l'amélioration de leur *épuration*, l'autre sur la carbonisation des *charbons flambants*,(1) autrement dit sur l'extension des possibilités de les incorporer dans les *pâtes à coke*.

L'évolution de la conjoncture économique depuis 3 ans n'a pu que renforcer l'importance de ces études:

au passage d'une période de vente facile à une période de stockage correspond une exigence accrue de la clientèle, un abaissement de la teneur en cendres moyenne des produits vendus; dans nos bassins du Centre et du Midi, où les charbons ont des *courbes de lavabilité* défavorables, le *rendement* de l'épuration en produits marchands tomberait à des valeurs inacceptables si l'on ne la perfectionnait pas.

le développement de la production du bassin lorrain, uniquement composée de charbons à haute teneur en matières volatiles, impose qu'il en soit consommé de plus en plus aux usages les plus rentables, c'est-à-dire cokéfaction pour les fractions inférieures à 6 ou 10 mm et chauffage domestique pour les *calibrés*.

Aussi les recherches des Houillères françaises, notamment dans leur Centre d'Études et Recherches (CERCHAR) se sont elles poursuivies dans ces différents domaines.

(1) Charbons flambants = high volatile bituminous coal [illegible]

Nos études antérieures avaient conduit aux résultats suivants:

a) on connaît facilement la courbe de lavabilité d'un charbon
b) nos campagnes d'essais ont défini la valeur intrinsèque des différents procédés de lavage du charbon, que caractérise aisément un coefficient unique, appelé *Imperfection* (1).
c) de la courbe de lavabilité d'un charbon et de l'Imperfection des procédés nous savons maintenant déduire le résultat de toute séparation d'un charbon brut en un charbon marchand, un *mixte* et un *schiste* à l'aide de tel ou tel procédé.

L'application de ces connaissances à de nombreuses mines françaises a été faite au cours des 5 dernières années:

— soit pour choisir les nouveaux lavoirs, la comparaison des rendements à escompter intervient parallèlement aux éléments de prix, frais d'entretien, complexité technique, etc...
— soit pour modifier les *coupures lavé-mixte* et *mixte-schiste* en vue d'obtenir la meilleure recette globale par tonne de charbon brut.

Pour faciliter ce travail, nous avons mis au point un nouveau mode de représentation graphique des *possibilités de lavage*.

Généralisant la représentation du Dr. Mayer, nous traçons, pour un charbon déterminé, un réseau de courbes C (R) correspondant chacune à une valeur déterminée de l'Imperfection.

Rappelons que dans ces diagrammes on porte en abscisses les proportions des fractions séparées et en ordonnées le poids C de cendres contenues dans la fraction considérée. Pour un appareil auquel correspond une courbe donnée, chaque point A de celle-ci représente une des séparations possible de 100 d'un produit brut contenant c de cendres par les segments

---

(1) Rappelons la définition de l'Imperfection I:

I = [illegible]
[illegible]
Densité de partage − 1

Les valeurs moyennes de I pour différents procédés sont [illegible]:

Bacs à grains	I 0,08 à 0,15
Bacs à fines modernes à alimentation [illegible]	I 0,11 à 0,15
Bacs à fines anciens à [illegible]	I 0,15 à 0,25
Tables pneumatiques [illegible]	I 0,20 à 0,25
Rhéolaveurs	I 0,15 à 0,35
Liquides denses [illegible]	I 0,02 à 0,05
Cyclones [illegible]	I 0,03 à 0,08

OA et AB, allant de l'origine des coordonnées au point B (100 ; ...) chaque ... des abscisses le poids R de produit pour 100 de brut, sur l'axe des ordonnées le poids C des cendres qu'il contient, et par conséquent pour pente sa teneur en cendres.

Un tel diagramme permet de répondre à toutes les questions qui peuvent se présenter en pratique :

séparation en deux, trois ou quatre produits,
possibilité de faire un *écrémage* pour obtenir du charbon très propre,
mélanges, etc...

Nous avons ensuite réalisé une *machine intégratrice* qui permet la construction rapide de ces diagrammes. Les principaux bassins et constructeurs français en ont une et sont ainsi à même d'étudier leurs problèmes.

Le Cerchar a déjà appliqué la méthode à près de 200 charbons divers. Elle convient, bien entendu, aux charbons étrangers, même très différents des nôtres. Ainsi, les fig. 1 et 2 donnent les courbes de lavabilité et les courbes de rendement pratique en fonction de la teneur en cendres qui nous ont été demandées pour un charbon brésilien.

COURBES DE LAVABILITÉ D'UN CHARBON BRÉSILIEN

WASHABILITY CURVES OF A BRAZILIAN COAL

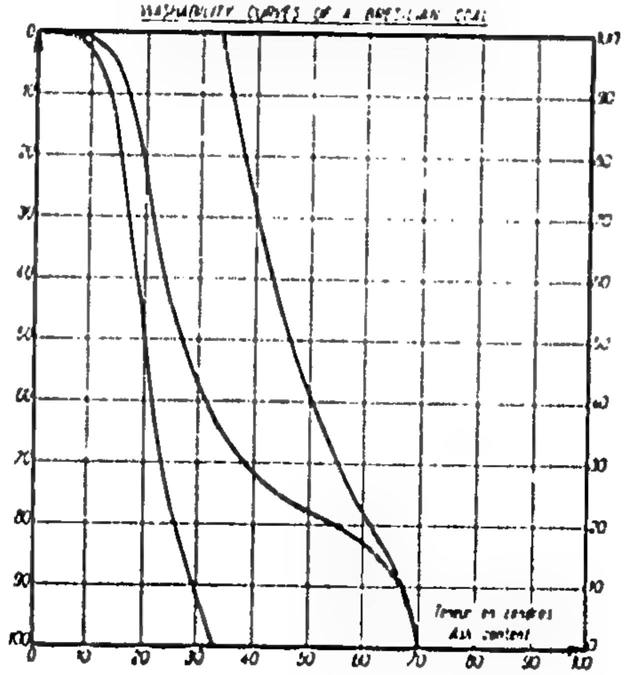

Fig. 1.

De même un constructeur français l'a appliquée à l'étude d'un lavoir pour fines de charbons.

Voici, à titre d'exemple, deux études récentes faites au Cerchar pour des mines françaises:

1er exemple:

A la mine de Decazeville, un vieux lavoir livrait à une cokerie des fines à 12% de cendres. La fourniture de fines à 9% de cendres devenant impérative, la mine doit étudier la construction d'un lavoir neuf. Quelles sont les conséquences techniques et financières à prévoir, du fait de la baisse de teneur du charbon lavé?

La fig. 3 donne, en haut, la courbe de lavabilité du brut: elle ne peut aucunement répondre à la question précédente: on voit en bas le réseau des courbes U (R) correspondantes.

La fig. 4, établie après tracé du réseau de la fig. 3 (5) donne le rendement en charbon lavé en fonction de la teneur en cendres de ce lavé et de l'Imperfection de l'appareil.

RENDEMENT PONDÉRAL SUIVANT L'IMPERFECTION DE L'APPAREIL DE SÉPARATION

YIELD FOR DIFFERENT VALUES OF APPARATUS IMPERFECTION

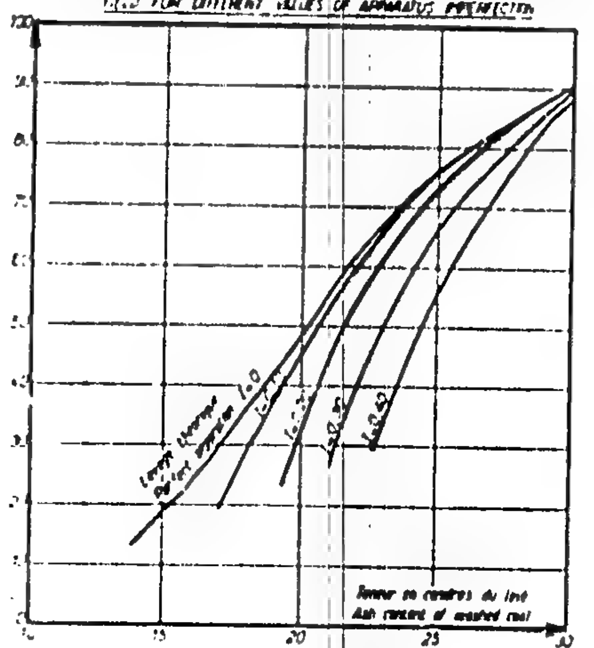

Fig. 4

(5) Toutes les figures de cette note ont été schématisées pour en faciliter la reproduction.

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L'imperfection des anciens bacs était de 0,25. L'imperfection des [illegible] sera certainement inférieure à 0,15. On lit sur les courbes les rendements en lavés suivants:

	lavé à 12%	lavé à 9%
Imperfection 0,25	62,5	51
" 0,15	65,5	55,5
Lavage parfait	67	59

La fig. 3 permet également de trouver la quantité et la teneur en cendres des mixtes. On a ainsi en mains tous les éléments nécessaires pour chiffrer les productions dans les différentes catégories, et la valeur marchande globale en fonction des barèmes.

2ème exemple:

La mine de Folschwiller envisageait une production, pour usages spéciaux de lavés, à 3% de cendres. Quel serait le rendement? Les produits restants, permettraient-ils de faire un lavé de 2ème choix à 12% et des mixtes?

La fig. 5 donne la courbe de lavabilité des fines traitées et le réseau des courbes U (R). L'Imperfection des bacs existants étant de 0,20 on peut en extraire (1) la réponse aux questions posées:

- rendement en lavé à 3% de cendres : 70%
- rendement en lavé à 12% de cendres : 8%
  mixte à 36% de cendres : 3%
- schiste à 75% : 19%

(la coupure entre schiste et mixte était placée à la valeur élémentaire de 55% de cendres).

B — *L'évolution des lavoirs français*

Je rappellerai d'abord qu'un sujet controversé est celui du lavage intégral: faut-il adopter cette solution, c'est-à-dire laver simultanément tous les *calibres*, et cribler ensuite, selon le système des bacs Baum très répandu en Angleterre et aux U.S.A.?; faut-il au contraire laver séparément chaque calibre, ce qui est toujours le cas en France? Nous res-

(1) Ou tout au moins de la fig. originale, établie en 50 x 75 cm

tons [illegible] de cette 2eme solution qui permet de *[illegible]* [illegible] rendement technique et financier de l'ensemble; cependant, nous devons à l'obligeance de nos collègues anglais du National Coal Board d'avoir pu procéder à des mesures précises sur un bac Jeffrey de la mine Gedling. Ici, la précision des compures est très moyenne, mais la courbe de lavabilité et la *courbe de répartition*

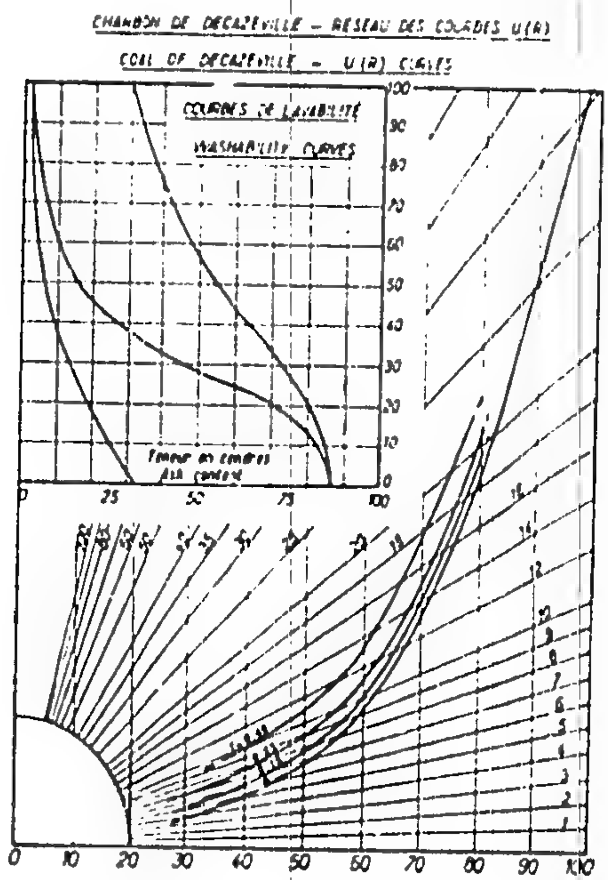

Fig. 3.

granulométrique de ce charbon sont très favorables, et les résultats sont excellents. Il est donc normal, dans de tels cas, et pour autant que l'on soit assuré, dans les années à venir, qu'ils resteront favorables, de profiter de la simplicité de cette méthode de traitement, mais nous n'avons pu trouver en France aucun cas particulier où ces conditions soient remplies.

Ceci dit, j'examinerai successivement les deux cas des chabons de [illegible].

Pour les *grains et calibrés* (au dessus de 10 mm) nos installations neuves sont pratiquement toutes à *liquide dense*, et essentiellement à magnétite: ces procédés ne sont, pour nous, pas plus chers que les autres, et la *précision de leur coupure* est toujours un avantage, grand ou faible selon le charbon traité.

CHARBON DE DECAZEVILLE – RENDEMENT PONDÉRAL SUIVANT L'IMPERFECTION DE L'APPAREIL DE SÉPARATION

COAL OF DECAZEVILLE – YIELD FOR DIFFERENT VALUES OF APPARATUS IMPERFECTION

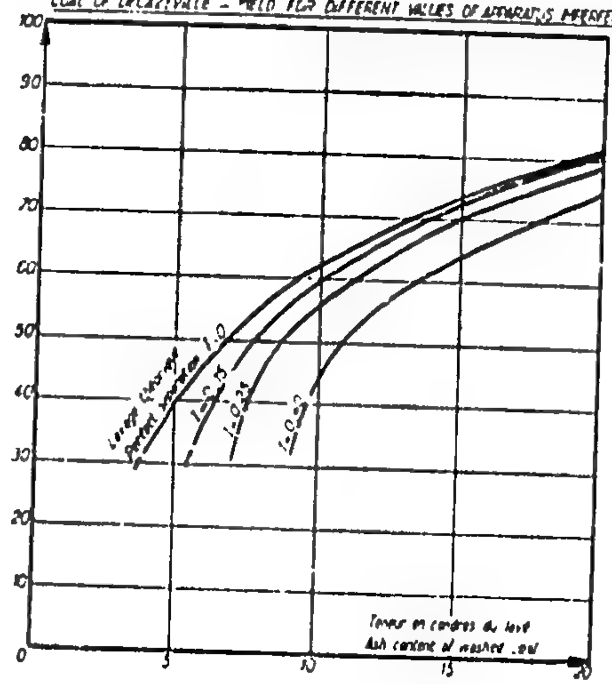

Fig. 6.

De nombreux procédés sont adoptés. Je citerai notamment, parmi les installations récentes:

- le procédé Tromp (*lavoirs* de Harnes, Blanzy, Carmaux, Meseix)
- le procédé Drew-boy de la Société PIC (lavoirs de l'Escarpelle, Douges, Merlebach, Graissessac, La Taladière).
- le procédé Staatsmijnen (lavoir Gayant)
- le procédé Nelson Davis (lavoirs d'Auchel et Mazingarbe)

Celui des Mines Domaniales de Potasse d'Alsace, dont nous avons fait la mise au point pour le charbon, en accord avec ces mines et avec

la Régie Française des Mines de la Sarre, a également donné de bons [illegible]ssai de Reden (Sarre) y est maintenant en fonctionnement industriel.

Jusqu'ici l'expérience ne permet pas de conclure que tel de ces procédés soit nettement plus favorable au lavage, et ce sont plutôt les qualités propres des constructeurs, telles que la compétence dans le choix de

FINES DE FOLSCHVILLER (LORRAINE). RÉSEAU DES COURBES U(R)

GRAINS OF FOLSCHVILLER (LORRAINE). U(R) CURVES

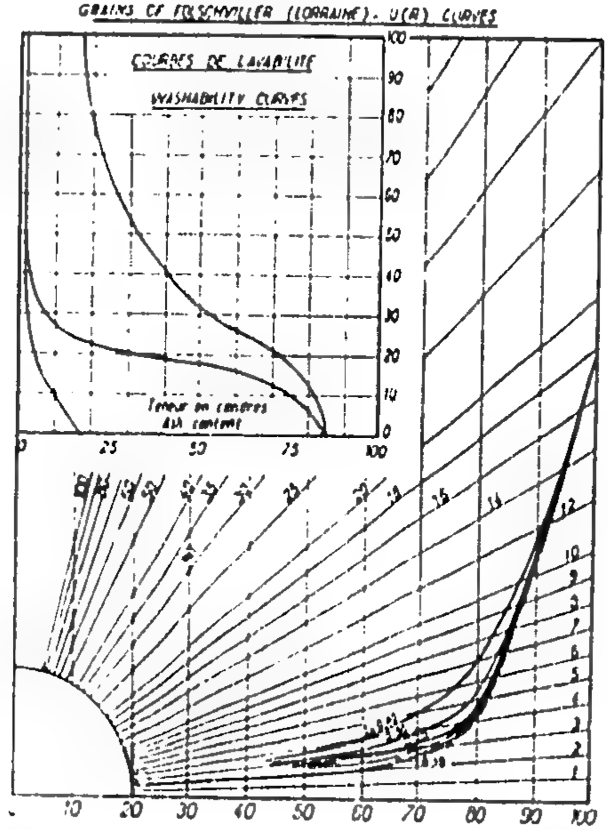

Fig. 5.

circuits simples, la robustesse du matériel, le prix, etc... qui semblent devoir les classer. Je ne m'attarderai pas à ces questions, qui relèvent de la concurrence commerciale; je signalerai que la consommation de magnétite, point important dans les pays sans approvisionnement propre, tombe dans certains cas à environ 250 g par tonne, et ne constitue plus un handicap gênant pour les solutions les mieux étudiées.

[illegible] 10 mm, les procédés centrifuges à liquide dense ne se développent pas rapidement en France. Ceci tient essentiellement à deux causes très distinctes:

— d'une part des considérations commerciales (brevets, exclusivités, etc....) freinent manifestement le développement du *cyclone à la magnétite*. Il aurait cependant l'avantage, ainsi que nous l'avons vérifié par des essais à l'échelle industrielle dans la Station d'Essai de Göttelborn de traiter du brut O-10 *non déschlammé*, avec une consommation de magnétite de 1,5 kg/t et une excellente *précision de coupure*.

— d'autre part, le bac à *commande pneumatique*, tel qu'il est couramment construit en France, donne d'excellents résultats lorsqu'on le calcule assez largement pour l'exploiter sans le surcharger. De nombreux essais sur ces appareils, en station d'essais puis dans plusieurs lavoirs, nous ont d'ailleurs conduits à préconiser un *lit filtrant* composé de cubes de céramique d'une densité voisine de 2,2 au lieu de feldspath. Cette substitution est toujours économique et améliore souvent l'imperfection, qui ne dépasse pas alors 0,11 à 0,15.

Aussi, dans les nouveaux lavoirs français compte-t-on pour ces calibres beaucoup de bacs et très peu de cyclones.

C — *Le problème des* très fins *et des* schlamms

L'ensemble des études mentionnées dans ce qui précède n'est pas terminé, mais est parvenu à un point où les progrès complémentaires ne pourront être que moins considérables. Aussi avons-nous ralenti leur poursuite pour reporter notre effort sur la question du charbon très fin.

La *fraction granulométrique* la plus fine de nos *charbons bruts* reste celle que les mines françaises considèrent comme la plus difficile et la plus onéreuse à traiter. Le principal souci de nos mines est donc d'abaisser la dimension des particules qu'il faut éliminer d'un charbon brut inférieur à 10 mm, parce qu'elle ne sont plus lavées efficacement avec le reste. A l'exception de quelques cas particuliers, par exemple celui du cyclone à la magnétite, cette coupure reste nécessaire et se place entre 0,2 et 0,5 mm.

Pour traiter le très fin ainsi séparé, le seul procédé industriel actuel est la *flottation*. Longtemps peu appréciée en France elle se développe beaucoup actuellement. Cependant on continue à trouver qu'elle est chère; les *filtres à vide* sont des appareils peu appréciés; enfin le produit récupéré contient encore 20 à 30% d'humidité, et cette teneur rend son utilisation parfois compliquée, ne serait-ce que par la difficulté de refaire des mélanges homogènes avec des fines propres. On souhaiterait donc trouver d'autres solutions.

Ceci explique l'intérêt porté en France au procédé Convertol de la Deutsche Kohlen Bergbau Leitung; plusieurs essais sont en cours dans nos bassins, avec la collaboration des spécialistes allemands. Sous sa forme la plus simple, le procédé n'a pas donné de bons résultats avec nos

[illegible] que la *fraction stérile* contient à la fois des éléments fins et des éléments plus grossiers: la séparation est mauvaise sur ces derniers, et la teneur globale en cendres du produit n'est pratiquement pas abaissée par l'élimination des plus fines argiles. Un schéma plus complet, dans lequel le produit brut mélangé d'huile passe d'abord dans une flottation sommaire avant *centrifugation* de la *fraction propre* va être étudié.

On peut actuellement espérer que le procédé ainsi modifié, ou d'autres *procédés à l'huile* que nous avons mis à l'étude seront, pour les schlamms français, plus intéressants que la flottation classique.

II – CARBONISATION DES CHARBONS FLAMBANTS

A – *Les recherches de base*

Nous appliquons aussi, dans ce domaine, la méthode qui consiste à mener, parallèlement aux essais pratiques, des recherches purement scientifiques, tendant à expliquer les phénomènes, et dont les résultats doivent normalement permettre d'accélérer les applications industrielles.

Puisqu'il est connu qu'on reproche aux charbons sarro-lorrains même s'ils sont bien fusibles (5), de donner lorsqu'ils sont *cuits* sans précaution spéciale, un coke bien trop petit et inapte à l'emploi au haut-fourneau, peut-on comprendre comment se fait la *fissuration du coke*, et pourquoi certaines *pâtes* se fissurent plus que d'autres?

Deux années de recherche de laboratoire ont conduit à l'explication du phénomène; le Cerchar en a publié le détail au cours de l'été 1953, mais la question est encore peu connue et mérite d'être résumée.

On sait qu'en chauffant, par exemple à la vitesse régulière de 2° C par minute qui est approximativement celle du four à coke, un charbon cokéfiable, il passe par diverses phases: – d'abord il reste pulvérulent et sa densité varie peu; – puis il "fond", les *grains* se rassemblent, la densité augmente notablement; – le dégagement des matières volatiles, qui a déjà commencé plus bas, s'accroît; la vitesse de ce dégagement est variable selon les charbons et, selon ses valeurs et celles de la fluidité de la pâte, la masse prend un aspect plus ou moins bulleux que l'on met très bien

	Indice de gonflement	M.V. sur matière organique pure	Indice Gray King
Gras A	7 9	31 36	G_2
Gras B	5 à 7	31 à 40	
Flambant gras	2 à 5	35 à 42	
Flambant sec	2	37 – 44	

(5) Rappelons les caractéristiques des différentes catégories de charbons sarro-lorrains.

en évidence en utilisant un four de chauffage équipé pour la radiogra[illegible] la fluidité diminue et l'on atteint, plus ou moins brutalement, autour de 500° un état de resolidification. Les matières volatiles continuent à se dégager, et le solide se contracte, d'abord rapidement, puis lentement, jusqu'à la fin du chauffage. C'est le phénomène qu'enregistre le *dilatomètre*, et qu'une transformation de cet appareil, permettant de l'utiliser jusque vers 1000°, nous a permis de mesurer avec exactitude. La fig. 6 donne l'exemple des courbes enregistrées avec un *charbon à coke peu fissurant* (Drocourt) et un charbon lorrain très fissurant (Ste. Fontaine), et des courbes de *coefficient de contraction* correspondantes *(courbes dérivées)*.

Pendant toute cette dernière période solide, la substance qui deviendra le coke et que E. Audibert appelle le protocoke, est soumise à des tensions internes que l'on voit clairement en chauffant, sur une paroi plane, une *galette* mince de charbon avec gradient de température entre les deux faces: celle-ci prend la forme d'une calotte sphérique dont la con-

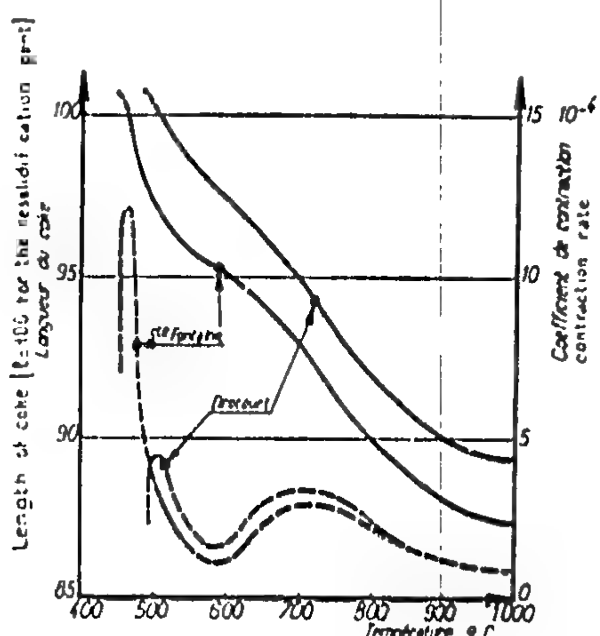

Fig. 6. Courbes de contraction de deux cokes à partir de leur point de resolidification (longueur à la resolidification = 100) et leurs courbes dérivées (en tirets).

Contraction curves for 2 cokes after their resolidification point and (dotted lines) value of the derivates

vexité est tournée vers la paroi chauffante, et dont le rayon de courbure [illegible] différemment selon les pâtes. Cette convexité s'explique sur la courbe donnant le coefficient de contraction en fonction de la température: à partir du moment où la couche mince est entièrement resolidifiée, sa face la moins chaude a un coefficient supérieur à celui de la face la plus chaude, et la différence des contractions crée cette courbure, qui varie dans le temps en fonction de l'évolution de ces coefficiens.

Lorsque la galette est plus épaisse, les courbures que les différentes couches élémentaires tendent à prendre sont incompatibles avec les liaisons qu'elles ont entre elles: la différence entre la contraction "libre" et la contraction réelle est donc un *"allongement contraint"* générateur de tensions internes qui croissent avec lui: quand il atteint *l'allongement à la rupture*, il y a fissuration qui gagne toute l'épaisseur de la galette. Ces allongements contraints peuvent se calculer à partir de la courbe dilatométrique.

Le four à coke s'assimile alors au cas d'une galette très épaisse: la zone de fusion progresse de la paroi vers le centre, et quand l'allongement contraint atteint l'allongement à la rupture, la fissuration intéresse l'épaisseur alors solidifiée. Or des expériences multiples montrent que, dans tous les phénomènes analogues, notamment le séchage du plâtre, la dessication des argiles céramiques, où un retrait tend à se produire et conduit à la fissuration, la maille de fissuration est sensiblement proportionnelle à l'épaisseur du solide fissuré. Ainsi aboutit-on à une loi approximativement linéaire entre la dimension du coke produit et l'écart des températures des faces de la croûte de coke qui se fissure, c'est-à-dire la température de resolidification, d'un côté, celle où l'allongement contraint atteint la valeur de rupture de l'autre.

Parvenue à ce point, l'étude considérée sur un plan purement théorique apparaîtrait sinon décevante, du moins d'intérêt bien limité, puisqu'on ne sait pas encore mesurer les allongements à la rupture du coke pendant son chauffage.

Heureusement, diverses observations apportent des simplifications qui permettent déjà de tirer parti de ces conclusions.

Les résultats expérimentaux de nos plus récents travaux montrent en effet pour la grande majorité des charbons étudiés jusqu'ici qu'il y a une relation *univoque* entre la valeur maxima α_m du coefficient de contraction, qui est la valeur à la température de resolidification, et le rayon de courbure final d'une galette d'épaisseur donnée, et que ces deux valeurs croissent régulièrement quand on classe les charbons du meilleur au plus mauvais, d'après ce que l'on sait de leur aptitude industrielle à donner du coke métallurgique.

Le même résultat est retrouvé, mathématiquement, si l'on suppose que l'allongement à la rupture a une valeur constante; cette hypothèse qui n'est certainement pas universellement exacte serait donc valable dans la majorité des cas.

Comme d'autre part la température de résolidification semble être [illegible] de a_2 (plus elle est élevée, plus a_2 est faible), ceci *met l'accent* sur l'importance des déterminations exactes des trois grandeurs dont nous venons de parler:

- *température de résolidification*
- *courbe dilatométrique après résolidification* et notamment valeur de a_2
- rayon de courbure des galettes.

Nos études se poursuivent, de ce fait, dans les directions suivantes:

1) amélioration des méthodes et des appareils de mesure.
2) extension des observations à des mélanges de charbons, ou de charbons et d'infusibles *(poussier de coke, semi-coke)*.
3) essai d'observation, par le procédé des galettes, — où l'échantillon est plus important et le permet au moins partiellement — de l'influence d'autres facteurs, tels que *granulométrie* et densité de la pâte, dont le rôle au four à coke est bien connu.

On peut espérer que cette deuxième partie de l'étude permettra d'aboutir prochainement à des applications industrielles: comparaison exacte des aptitudes à cokéfier des charbons variés, de mélanges variés, y compris le contrôle permanent des pâtes par des procédés de laboratoire simples, donnant des renseignements correspondant vraiment à la qualité du coke industriel qu'ils donneraient, toute réserve étant faite bien entendu — comme elle l'est déjà sur les mesures actuelles faites à postériori sur le coke (shatter-test, *Micum*, etc. . .) — sur la difficulté d'apprécier ce qu'est le bon coke correspondant à chaque usage et à chaque usager.

Un tel résultat étendrait la gamme des charbons à cokéfier tant en permettant à priori de les utiliser, à caractéristiques données du coke, qu'en améliorant la régularité de sa fabrication, donc la sécurité de marche du haut-fourneau l'utilisant et par conséquent en permettant d'être moins exigeant sur les caractéristiques imposées.

B — *Les recherches pratiques*

Nous avons condensé dans une Communication à la Conférence Sidérurgique de Bogota (Octobre 1952) les résultats obtenus de 1919 à 1952 dans l'emploi effectif des charbons sarro-lorrains dans les pâtes à coke métallurgiques. Ces résultats pouvaient se résumer ainsi:

1) sans aucune installation complémentaire et *sans pilonnage*, on peut employer 40% de "gras B".

2) dans une cokerie avec pilonnage, la technique Carling permet d'employer un mélange de "gras B" et "flambant gras" à concurrence de 82% du charbon cru, ou un "flambant gras" à concurrence de 70%, le charbon d'appoint est un charbon à coke très fluide qui intervient certainement en relevant la température de résolidification. A ce mélange de charbons crus on ajoute selon les formules, 7 à 12% de poussier de coke.

[illegible] de l'installation Sovaco (tables chauffants et *broyages sélectifs*), mais sans pilonnage, la proportion de "gras B" et "flambant gras" mélangés atteint 60% de la pâte.

4) le semi-coke pulvérulent a un effet analogue a un effet analogue à celui du poussier de coke, meilleur ou moins bon selon les pâtes. Son emploi permet de faire participer des "flambants secs" à la carbonisation

Ces études ont été depuis lors activement poursuivies:

a) Les formules types utilisées à Carling, avec une *densité de chargement* de 1000 à 1100 kg de charbon humide par m³ de four, sont aujourd'hui les suivantes:

Formules	*Charbon lorrain*		*Poussier de coke*	*Appoint*
A	"Gras A"	: 80 à 85%	15 à 20%	0
B	"Gras B"	: 75%	16%	9%
C	"Flambant gras"	: 62 à 65%	7 à 8%	28 à 30%

Avec la même technique, la Cokerie de Reden (Sarre) utilise couramment le mélange suivant:

75 à 70% de "gras A" de la Mine de Reden
10 à 15% de "flambant gras" de Reden
10% de 1/2 gras Ruhr ou Aix-la-Chapelle
5% de poussier de coke

qui donne un excellent coke (indices Micum — M 10 > 81; M 10 < 7,5.[6]
Elle a eu récemment des essais satisfaisants avec une pâte composée de:

"Gras A" 82%
"Flambant gras" 10%
"Poussier de coke" 8%

ceci à condition de broyer le poussier de coke à une finesse encore plus grande avec des broyeurs à boulets analogues à ceux des cimenteries, et de parfaire le broyage et l'homogénéité du mélange final par un passage dans une deuxième série de broyeurs CARR.

b) La cokerie de Thionville, équipée en technique Sovaco, a pu utiliser en avril-mai 1953, un mélange comprenant 70% de charbons sarro-lorrains, savoir:

"Gras A" sarrois 25%
"Gras B" lorrains 20%
"Flambant gras" lorrains . 25%
"Gras de la Ruhr" 15%
"*Demi-gras* d'Aix-la-Chapelle 15%

et dont le coke a des indices Micum M 10 et M 10 respectivement égaux à 77,2 et 7,2 donc est tout-à-fait apte à l'emploi dans nos hauts fourneaux.

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(6) Résultats des mesures au tambour Micum (M 10 : fraction du + 10 mm)
M 10 : fraction du — 10 mm)

c) La Cokerie Expérimentale de Marienau, avec la méthode de *l'en* [illegible] a obtenu du bon coke avec un mélange:

"Gras B"	60 à 65%
Charbon à coke (Ruhr)	25 – 30
Semi-coke	10

Elle étudie la production de semi-coke par *fluidisation.* Le procédé a donné de bons résultats à l'échelle de 100 kg/h et une unité de 1 t/h sera en service à la fin de 1953.

Les progrès réalisés de ces divers côtés se traduisent dès maintenant par la progression régulière des tonnages de charbon lorrain utilisé à la production de coke sidérurgique:

1947	495.000 tonnes	1951	735.000 tonnes
1948	575.000 "	1952	805.000 "
1949	559.000 "	1953 (sur la base des 9 premiers mois	890.000 "
1950	473.000 "		

En outre, elles justifient le développement des cokeries des mines et des usines sidérurgiques du bassin lorrain, et permettent de choisir leurs caractéristiques en vue de cette consommation. Nous citerons à ce propos les chiffres suivants:

1) la capacité d'enfournement journalier totale des cokeries en service de ce bassin est la suivante.

– Cokeries des mines	2.650 t/j	
– Cokeries des usines sidérurgiques .. .	8.350 t/j	
Total		11.000 t/j

2) Les constructions en cours sont les suivantes:

– Cokeries Minières	Carling	700 t/j		
	Marienau	2.400 t/j	3.100 t/j	
– Cokeries sidérurgiques	Longwy	700 t/j		
	Pont-à-Mousson ..	500 t/j		
	Hagondange	600 t/j		
	Moyeuvre	450 t/j		
	Sollac	1.150 t/j	3.400 t/j	6.500 t/j

III. – UTILISATION DES CHARBONS FLAMBANTS DANS LES [illegible] CHAUFFAGE DOMESTIQUE

L'emploi des charbons flambants dans les appareils de chauffage domestique: poêles ou petites chaudières de chauffage central, se heurte à des difficultés de deux ordres:

1°. Ces charbons renferment une proportion élevée de matières volatiles qui se dégagent avant que le charbon n'atteigne la zone de combustion. Dans les appareils de type classique, ces matières volatiles sont entraînées à la cheminée sans avoir rencontré des conditions qui leur permettent d'assurer leur combustion complète; il en résulte une perte importante par *imbrûlés* à la cheminée, donc un rendement thermique réduit, ce qui n'est généralement pas considéré par l'usager comme un inconvénient très sérieux; l'ennui le plus grave réside dans les dépôts de *suies* et de goudrons qui encrassent très rapidement la cheminée.

2°. La plupart des charbons flambants possèdent une certaine *aptitude à la fusion et à l'agglutination* lorsqu'ils sont chauffés assez rapidement; ce phénomène s'oppose à une descente régulière du combustible dans le poêle ou la chaudière; il se forme des *voûtes* qu'il faut briser par de fréquentes interventions manuelles, faute de quoi l'allure de combustion demeure très irrégulière.

Les charbons de Lorraine présentent à cet égard des caractéristiques variées. Les "flambants secs" qui ne fondent pas lorsqu'ils sont soumis à une *loi de chauffage* de quelques degrés minute comme celle que l'on rencontre dans les fours à coke, donnent lieu fréquemment à une légère agglomération dans les poêles, car la loi de chauffe y est généralement plus rapide. Les "flambants gras" s'agglomèrent très sensiblement dans les poêles.

Les deux difficultés que nous venons de signaler se rencontrent également dans les foyers industriels, mais les moyens mécaniques dont ils sont généralement pourvus *tirage soufflé, poussoir, vis d'alimentation*, etc., leur permettent de s'en accommoder. Dans les poêles le problème est beaucoup plus difficile car les seules forces dont on dispose sont la force de gravité pour assurer la progression du combustible, et le tirage naturel pour provoquer la circulation de l'air.

Le problème n'est pas spécial à la France, mais aucune solution étrangère ne peut nous convenir. Ainsi le poêle Martin, résultant des recherches du "Bituminous Coal Research" des U.S.A. donne dans nos conditions d'utilisation des fumées trop chaudes, avec des risques de renversement de tirage, qui ne peuvent être acceptés.

Après quelques années d'efforts plusieurs constructeurs français en liaison étroite avec les Charbonnages ont abouti à la mise au point de plusieurs poêles d'un type nouveau et basés sur les principes suivants:

La combustion du charbon s'effectue en couche mince à la base d'une trémie verticale, l'air primaire circulant à peu près transversalement. Pour faciliter la descente du charbon, la trémie possède parfois

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une certaine *dépouille*; en outre, une petite fraction du courant *d'air primaire* circule de haut en bas dans la trémie pour entraîner vers le bas les matières volatiles et les obliger à traverser la zone de combustion; ce courant d'air réalise également une certaine *préoxydation* du charbon.

La combustion des matières volatiles est obtenue, comme dans les appareils industriels, en ménageant à la suite du foyer proprement dit une chambre de combustion dans laquelle on introduit de l'air secondaire; cette chambre est disposée de telle sorte que sa température soit relativement élevée; elle est généralement garnie de réfractaire; l'air secondaire est parfois préchauffé par une circulation convenable avant son entrée dans la chambre de combustion.

Ayant monté au Cerchar une plateforme d'essai scientifique de ces appareils, nous avons pu préciser leurs principales caractéristiques;

Tous ces poêles réalisent correctement la combustion des matières volatiles et les fumées qui s'échappent à la cheminée ne renferment pas plus d'imbrûlés solides (imbrûlés gazeux, goudrons et suies) que les fumées d'un poêle classique alimenté en charbon maigre; ils peuvent être montés sur une cheminée ne présentant pas de caractéristiques spéciales; ils fonctionnent avec une dépression d'environ 1 mm d'eau. Leur aptitude à utiliser des charbons agglutinants est très diverse. La plupart ne s'accommodent que de "flambants secs"; d'autres peuvent accepter les "flambants gras" les moins agglutinants; aucun d'eux n'est capable de brûler régulièrement tous les "flambants gras".

Ces résultats n'ont encore qu'un intérêt pratique limité: il faut pouvoir assurer aux propriétaires de ces poêles un approvisionnement en qualités étroitement définies, mais ils sont encore peu nombreux, clients de négociants multiples, qui n'ont pas le débouché suffisant pour les satisfaire régulièrement, et ceci n'est possible que dans quelques localités spécialement suivies. La recherche de poêles pouvant consommer une gamme plus étendue de "flambants" résoudrait cette difficulté et se poursuit; il faudra en même temps qu'on puisse en abaisser le prix de vente, afin qu'il soit voisin de celui des appareils à combustibles anthraciteux ou maigres.

Cet effort n'est d'ailleurs qu'un des aspects de la politique d'ensemble des Charbonnages de France, tendant à suivre de mieux en mieux la consommation du charbon, à conseiller les usagers, à faire des agents commerciaux des spécialistes de l'utilisation des différentes qualités, et à encourager techniquement et financièrement les progrès du matériel de chauffage. Il y a toute chance que cet ensemble de mesures conduise prochainement à des progrès sensibles.

CONCLUSIONS

Les qualités des charbons sont très diverses, mieux on sait tirer parti de chacune plus on améliore, d'une part, les ressources mondi[illegible] utilisables, plus on facilite d'autre part, sa consommation locale, économisant

… dans ce domaine sert donc non seulement l'intérêt d'un producteur contre ses concurrents, mais l'intérêt général bien compris.

Il reste beaucoup à apprendre: des propriétés physiques et chimiques de la houille, substance complexe et peu étudiée par les laboratoires de science pure, on ne connait que quelques fragments; les études d'utilisation sont donc encore très empiriques, et de portée limitée

J'espère avoir montré que les Charbonnages de France s'efforcent de progresser dans cette double voie et que, ne sous-estimant pas l'ampleur de la tâche, ils lui consacrent dans l'effort général de recherche entrepris avec persévérance depuis plus de 7 ans, des moyens non négligeables, grâce auxquels certains résultats appréciables ont déjà été obtenus.

RÉSUMÉ

Suivant l'évolution de la conjoncture économique, les recherches des Houillères françaises, notamment dans leur Centre d'Études et Recherches (Cerchar) se sont développées dans les trois domaines suivants: amélioration de l'épuration des charbons, carbonisation des charbons flambants, utilisation de ces derniers au chauffage domestique

Amélioration de l'épuration. - Pour ses recherches de base, le Cerchar a mis au point et fréquemment appliqué un nouveau mode de représentation graphique des possibilités de lavage

Évolution des lavoirs français: adoption des procédés à liquide dense à la magnétite pour les grains, tandis que, pour les fines, le cyclone n'a pas pris jusqu'ici la place des bacs pneumatiques à lit filtrant. Pour les très fins et les schlamms, la flottation se développe

Carbonisation des charbons flambants Parmi ses recherches fondamentales, le Cerchar s'est particulièrement attaché à l'étude de la fissuration au cours de la carbonisation: étude des tensions internes par chauffage d'une galette de charbon sur paroi plane; détermination de la température de resolidification après fusion et examen dilatométrique après cette resolidification

Les recherches pratiques sur l'extension de l'utilisation des charbons sarro-lorrains dans les mélanges pour cokéfaction ont été effectuées:

1.° à la cokerie de Carling (Lorraine) et à celle de Reden (Sarre) avec la méthode du pilonnage.
2.° à la cokerie de Thionville (Lorraine) en utilisant la technique du broyage sélectif;
3.° à la cokerie expérimentale de Marienau (Lorraine) avec la méthode de l'enfournement à sec, en mélange avec du semi-coke de charbons lorrains

Données numériques sur la progression des tonnages de charbons lorrains ainsi utilisés et sur l'extension des cokeries

Utilisation des charbons flambants dans les poêles de chauffage domestique

Les recherches concernent les deux principales difficultés à surmonter: d'une part la teneur élevée en matières volatiles entraînant des pertes à la cheminée et des dépôts de suies et de goudrons, d'autre part l'agglutination qui nuit à la descente de la charge.

Divers types de poêles français et étrangers pour charbons flambants ont été étudiés au Cerchar sur plateforme d'essais.

SUMMARY

Taking into consideration the evolution of economics, research work of french collieries, specially of their Research Center (Cerchar) has been oriented toward 3 fields: improvement in coal cleaning, carbonization of high volatile coals, use of those coals to domestic heating.

Improvement in coal cleaning —

As a basic research work, Cerchar has developed and often used a new graphical representation for the cleaning possibilities.

Development of the french preparation plants: adoption of magnetite heavy media for peas, for grains, cyclone has not yet been substituted to pneumatic jigs with filtering bed, for fines and slurry, flotation is gaining ground.

Carbonization of high volatile coals —

As fundamental research work, Cerchar investigated formation of cracks during carbonization, development of internal stresses when heating a thin coal cake on a plate, determination of resolidification temperature after fusion and observations with the dilatometer after resolidification.

Practical research on extended use of Sarre-Lorraine coals in the coking blends has been conducted:

1° at Carling (Lorraine) and Reden (Sarre) with the stamping process.
2° at Thionville (Lorraine) with the selective grinding process.
3° at the experimental coke ovens at Marienau (Lorraine), with the dry loading process, and addition of char produced from Lorraine coals

Statistical data showing the increasing use of Lorraine coals, together with the increase of coke oven plants

Use of high volatile coals in domestic stoves —

Research concerns the two main difficulties, namely the high volatile content, which increases the heat losses at the stack and the soot and tar precipitation — the caking tendency which hinders a smooth down fall of the fuel.

Various French and foreign models of stoves designed for high volatile coals have been tested by Cerchar on special testing benches.

Resumo

De acôrdo com a evolução de sua economia, as pesquisas das minas de carvão francesas, especialmente no seu Centro de Pesquisas (Cerchar), desenvolveram-se nos três seguintes domínios: melhora na purificação ou lavagem do carvão, na carbonização dos carvões betuminosos altamente voláteis, e no uso dêstes para o aquecimento doméstico.

Melhora na Lavagem do Carvão. — Para suas pesquisas de base, Cerchar desenvolveu e, frequentemente, utilizou uma nova representação gráfica para as possibilidades de lavagem.

Evolução dos processos de lavagem: adopção do liquido pesado de magnetita para o carvão em cavilha; para o carvão em grãos o ciclone pulverizador ainda não substituiu as caixas pneumáticas com leito de filtração; e para os carvões miúdos e lamacentos a flutuação vai sendo preferida.

Carbonização dos Carvões Altamente Voláteis. — Entre suas pesquisas fundamentais, Cerchar se dedicou, particularmente, ao estudo das rachaduras durante a carbonização, à manifestação das tensões internas pelo aquecimento dum pequeno bolo de carvão (gallete) numa chapa; determinação da temperatura de ressolidificação depois da fusão e exame com o comparador de dilatação sólida retro ativo depois da ressolidificação.

As pesquisas práticas sôbre o alcance do aproveitamento dos carvões de Sarre e Lorraine nas misturas de coqueificação (transformação em coque) foram efetuadas:

1.º — nos fornos de coque de Carling (Lorraine) e Reden (Sarre) com o método de pilagem;
2.º — nos fornos de coque de Homécourt (Lorraine) com a técnica da moagem seletiva;
3.º — nos fornos experimentais de coque em Marienau (Lorraine) com o método de secagem, em mistura com o semicoque (carvão animal) produzido dos carvões da Lorraine.

Dados estatísticos sôbre o emprêgo crescente de carvões da Lorraine assim utilizados e sôbre o aumento dos fornos de coque.

Emprêgo dos Carvões Altamente Voláteis nos Fornos Domésticos. As pesquisas são relativas às duas principais dificuldades que devem ser superadas: de um lado o conteúdo elevado em matérias voláteis de que resultam perdas na chaminé e depósitos de fuligem e de alcatrão, e do outro lado a aglutinação que prejudica a descida da carga.

Diversos tipos de estufas francesas e estrangeiras para carvões voláteis foram estudadas por Cerchar sôbre plataforma especial de "tests".

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ROY M.
LEGENDRE R.
France

VUES COMMUNES DES INDUSTRIELS FRANÇAIS S'INTÉRESSANT AUX TURBINES À GAZ OU AUX GÉNÉRATEURS DE GAZ À PISTON LIBRE

Par M. ROY

et R. LEGENDRE

COMITÉ NATIONAL FRANÇAIS

INTRODUCTION

La première turbine à gaz industrielle fut réalisée en France au début du vingtième siècle par Armengaud et Lemale, et stimula en divers pays les travaux de quelques spécialistes dont les chances de succès allaient croissant à mesure des progrès des turbomachines.

Un éminent ingénieur français, Rateau, fut l'un des principaux artisans de ces progrès et l'un de nous put s'appuyer notamment sur son oeuvre pour tracer, dès 1928, les grandes lignes des applications de la turbine à gaz à l'aviation [1].

Il fallut néanmoins attendre près de dix ans pour que des études de turbines à gaz, destinées à l'Aéronautique ou à la Marine, après un effort studieux peu connu, fussent entreprises à peu près simultanément en France, en Grande-Bretagne et en Allemagne, tandis que des études de turbines à gaz industrielles étaient déjà en cours en Suisse.

Le développement de toute machine nouvelle exige de nombreux efforts et de puissants moyens financiers que les nécessités de la guerre font souvent consentir plus facilement. Ainsi, la seconde guerre mondiale a-t-elle vu à la fois l'apparition et le succès technique du turboréacteur d'aviation, de la fusée géante et de la bombe atomique.

Placée, par sa position géographique, sur le chemin des grands courants intellectuels comme sur celui des grandes armées, la France a aussi bien participé aux grands progrès de la technique qu'elle a subi de

grandes dévastations. Des dommages matériels retardent parfois [illegible] mais [illegible] acquise est un puissant ressort, si bien qu'en dépit de difficultés sociales consécutives à toute période troublée, la France reste le pays du sage Descartes et des tenaces soldats de Verdun.

Le présent rapport a pour objet l'exposé des principaux résultats acquis par les industriels français qui s'intéressent tant à la turbine à gaz proprement dite qu'à l'une des machines qui peuvent lui être associées, à savoir le générateur de gaz à pistons libres. Il indique également le sens dans lequel l'effort est poursuivi, avec pondération et continuité, ainsi que les réalisations qui peuvent être entreprises raisonnablement pour satisfaire les intérêts communs des utilisateurs et des constructeurs.

Fig. 1 — Station de compression du laboratoire de la turbine à gaz entraînée par une turbine à gaz RATEAU de 4 000 ch à 550°c alimentée par un foyer construit par l'Établissement National d'Indret

L'IMPULSION INITIALE

Si le grand public, après avoir ignoré les patients efforts des pionniers, s'est enthousiasmé soudainement pour la turbine à gaz au point parfois de s'attendre à la voir se substituer à toutes les autres machines thermiques, parce qu'elle a éclipsé le moteur à explosion dans l'aéronautique en quelques années, l'ingénieur averti sait par contre qu'il n'existe pas de formule magique, et ce ne serait certainement pas servir le développement de la turbine à gaz que de préconiser son emploi de façon inconsidérée.

[illegible] nouvelle [illegible] grand service public, [illegible] la satisfaction de ses besoins.

Aussi, en France, les premières turbines à gaz des deux types [illegible] furent commandées par la Marine Militaire, qui est et restera l'un des principaux utilisateurs en dehors de l'Aviation.

Après la seconde guerre mondiale, les progrès accomplis et la limitation des crédits militaires recommandaient un élargissement des applications. Des représentants de tous les Services Publics susceptibles d'être intéressés par les machines nouvelles furent rassemblés en un organisme dénommé Commission interministérielle de la Turbine à gaz. M. Pierre

Fig. 2 — Plateforme d'essai des générateurs de gaz à pistons libres

[illegible], Directeur des Industries Mécaniques et Électriques, ayant été l'un des principaux initiateurs des applications à la Marine Militaire. Il nous fit l'honneur, en faisant instituer cette Commission interministérielle, de nous en faire confier [illegible] les fonctions de Président et de Rapporteur.

Le rôle essentiel de cette Commission a été d'assurer une action concertée des utilisateurs relevant des Administrations publiques, de façon à éviter une dispersion des efforts des constructeurs.

Les considérations économiques qui déterminent le choix d'une machine sont trop étroitement liées aux caractéristiques techniques pour qu'il soit possible de résumer ici les débats de la Commission et il suffira ici d'indiquer que les principales conclusions furent les suivantes.

- les premiers débouchés importants des turbines à gaz se trouveront [illegible] les dépenses de combustible ont une importance assez faible par rapport à celle des frais de premier établissement, d'entretien et de personnel, de sorte qu'il n'est pas indispensable associer, au moins au départ, un très haut rendement à l'emploi d'un combustible de faible prix;
- il n'est pas judicieux de concurrencer les machines thermiques en usage pour des fonctions auxquelles celles-ci sont particulièrement bien adaptées de sorte que ni une centrale électrique constituée de turbines à gaz à puissance comparable à celle des turbines à vapeur qui entraînent les alternateurs modernes, ni le moteur d'une petite voiture automobile ne correspondent à des applications raisonnablement économiques à brève échéance.
- au contraire, chaque fois que, pour une application particulière, l'installation d'une turbine à vapeur apparaît trop onéreuse, ou l'alimentation en eau d'un condenseur trop difficile, ou les frais d'entretien et de conduite d'un moteur Diesel trop élevés, l'emploi d'une turbine à gaz mérite d'être pris sérieusement en considération

Ces conclusions furent mises en œuvre dans les commandes que les Services Publics passèrent à l'industrie nationale, et dont les résultats seront indiqués ultérieurement

L'ACTION DES INDUSTRIELS

Les constructeurs ont donné toute leur compréhension à l'action des Pouvoirs Publics inspirée par le souci de l'intérêt général. Aujourd'hui, ils peuvent élargir leur horizon en développant les résultats acquis par les premiers efforts ainsi suscités et soutenus

Si un industriel sérieux doit veiller à n'installer loin de ses usines que des machines d'un type largement éprouvé dans son pays, on verra plus loin que cette condition est déjà largement satisfaite pour plusieurs turbines à gaz françaises

D'autre part, les pays qui sont aujourd'hui sur la voie d'une rapide expansion économique offrent des possibilités très étendues aux innovations raisonnables. Lorsqu'elle est bien conçue, la turbine à gaz est, dès maintenant, la machine qui s'accommode des moindres servitudes, de sorte qu'elle peut être installée à faibles frais dans une exploitation nouvelle et bénéficier de ses avantages foncièrs d'autonomie, déjà si pleinement illustrés par les machines d'aviation et sur lesquels l'un de nous insistait naguère particulièrement [2]

Pratiquement, les industriels qui s'intéressent le plus aux turbines à gaz sont ceux qui déjà produisent d'autres types de machines thermiques. Ils savent donc choisir le compromis judicieux, et n'ont pas tendance à proposer une turbine à gaz là où un appareil moins nouveau peut donner entière satisfaction

Les domaines d'application dépendent naturellement des types de [illegible] combustible, que nous allons maintenant examiner pour [illegible] les résultats acquis et pour indiquer le sens de l'évolution actuelle.

LES TYPES DE TURBINES A GAZ

Bien que la France puisse s'enorgueillir de belles réalisations dans le domaine de l'aéronautique et particulièrement des petites machines de la Société TURBOMECA qui a concédé des licences à plusieurs grands pays, il n'y existe pas dans le domaine aéronautique, et contrairement à ce qui existe dans le domaine non aéronautique, une action concertée des constructeurs de turboréacteurs qui nous permettrait ici de parler en leur nom.

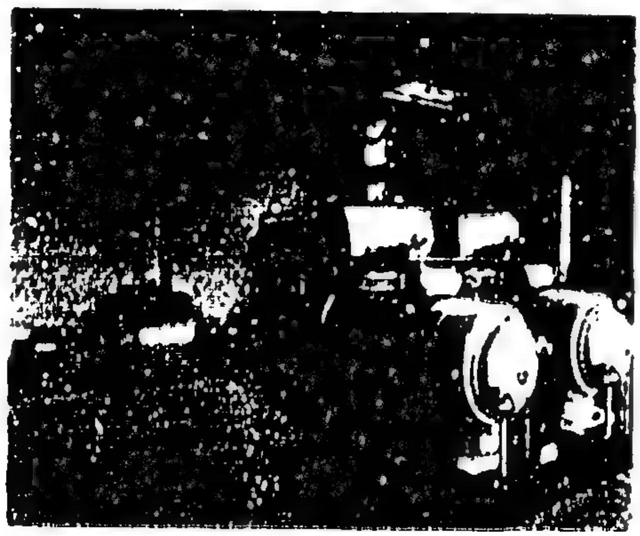

Fig. 3 — Groupe électrogène de 1 500 kW « S I G M A — ALSTHOM »

Concernant les turbines à gaz industrielles ou marines réalisées en France, on a déjà dit qu'elles se classent en deux catégories, à savoir : les turbines qui détendent les gaz chauds sous pression produits par des générateurs à pistons libres, et les ensembles composés uniquement de turbomachines.

La description de ces machines, qui n'aurait pas sa place dans le présent rapport, a fait l'objet, dans la presse technique, de nombreux articles qui précisent les conceptions particulières de chacun des constructeurs.

Rappelons seulement que le générateur de gaz à pistons libres est un moteur Diesel simplifié, rendu plus robuste, plus facile à construire,

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[illegible] turbine utilisant des gaz de générateurs [illegible]

Les ensembles de turbomachines conçus en France restent aussi simples que le permet le respect d'un rendement déterminé, mais toujours fixé par l'utilisateur à une valeur modeste. Cependant il ne s'agit pas comme en aviation de recourir à des températures très élevées pour obtenir un rendement acceptable avec le circuit "le plus simple", de sorte qu'une turbine à gaz industrielle ou marine établie pour un rendement de 25%, avec une température maximum inférieure à 700°C., pourra comprendre 3 ou 4 machines tournantes, un ou plusieurs refroidissements en cours de compression, éventuellement une réchauffe en cours de détente.

Les deux types de machines sommairement rappelés ci-dessus, sont tout différents, mais ils offrent cette particularité commune d'intéresser les mêmes utilisateurs et les mêmes constructeurs. Sur le plan du présent examen les conditions de leur développement peuvent être discutées simultanément.

LES COMBUSTIBLES

Aucun emploi direct de combustibles solides dans les turbines à gaz n'est envisagé par les industriels français. Certes, aucun problème technique n'est probablement insoluble en toute rigueur, mais une sage action n'est pas moins efficace si elle consacre ses premiers efforts aux problèmes les moins ardus.

Pour beaucoup d'applications, notamment toutes celles du moteur Diesel ou celles des Marines militaire ou commerciale, l'emploi de combustibles liquides est déjà accepté, et la turbine à gaz trouve là un champ assez large pour sa première expansion. Il semble, d'ailleurs, assez peu douteux que des considérations de propreté, de confort du personnel, de facilité d'exploitation imposeront de plus en plus la généralisation de l'emploi des combustibles liquides pour tous les engins mobiles.

Le générateur à pistons libres, parce que le mouvement de ses pistons n'est pas lié par une manivelle, peut brûler un combustible plus lourd que celui acceptable pour un moteur Diesel de même cylindrée et de même fréquence de battement. Ces dernières caractéristiques peuvent, en outre, être choisies avec plus de souplesse.

En fait aucune difficulté ne s'oppose à l'emploi d'un combustible lourd dans le foyer d'une turbine à gaz composée de turbomachines, si la température est raisonnablement limitée, comme il va de soi, pour ne pas prétendre vainement à égaler le rendement du moteur Diesel qui brûle un combustible de luxe.

La turbine de 5000 ch du Laboratoire exploité par l'Association pour la Turbine à Gaz fonctionne sans incident depuis trois ans, bien

que son foyer soit alimenté avec des mazouts lourds de provenances va[illegible] [illegible]pérature de sortie du foyer est limitée à 650° C.

Notons que des déchets d'huile végétale peuvent parfaitement convenir à l'alimentation d'un foyer.

Le gaz de fours à coke et le gaz naturel, sont d'excellents combustibles pour turbines à gaz fixes, et le gaz de haut-fourneau convient également moyennant une adaptation du foyer.

Une mine de charbon située dans une région désertique, ou dont les produits sont impropres à la combustion dans les chaudières, peut alimenter un gazogène, simple haut-fourneau fonctionnant sans minerai de fer ou fournissant un peu de fonte comme sous-produit et dont le gaz dépoussiéré peut être consommé directement par une turbine à gaz.

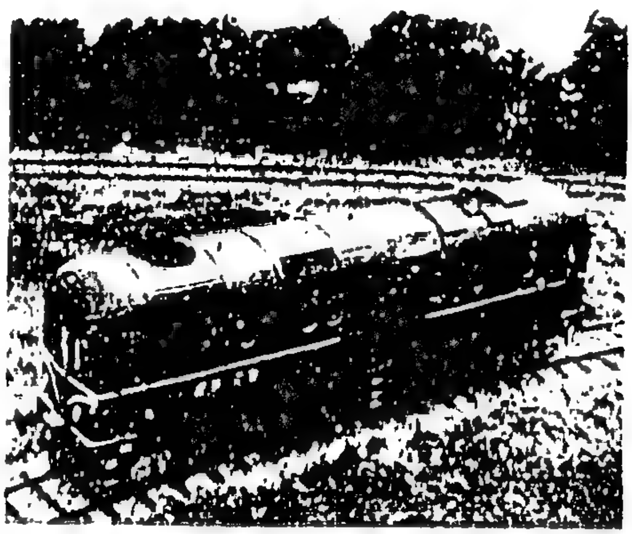

Fig. 4 — Locomotive Renault de 1 000 ch à moteur "S.I.G.M.A. — RATEAU".

LES RESULTATS ACQUIS

La Marine Militaire a encouragé le développement des générateurs à pistons libres en vue de leur utilisation sur les bâtiments de surface à puissance propulsive modérée. La turbine à vapeur n'est, en effet, économique que pour les très grandes puissances et lorsque la marge entre le régime de croisière et le régime de combat n'est pas excessive. Le moteur Diesel, de son côté, peut difficilement suivre l'évolution que l'accroissement des exigences militaires rend nécessaire, même pour les petits bâtiments. Le générateur à pistons libres trouve ainsi, dans un domaine intermédiaire de puissance, des possibilités intéressantes grâce à sa sim-

plicité, sa légèreté, sa souplesse d'installation, ses facilités d'entretien, et [illegible] possible tout à fait comparable à celle du moteur Diesel.

Bénéficiant d'une mise au point prolongée et minutieuse, les générateurs à pistons libres sont construits en série par la Société Industrielle Générale de Mécanique Appliquée (S.I.G.M.A.). Un bon nombre de chantiers français de constructions navales installent, ou se préparent à installer, de tels générateurs avec le concours de constructeurs de turbines axiales ou radiales. Les premières turbines associées à ces générateurs sont construites par la Société Alsthom et par la Société Rateau. Les premiers navires de surface sont équipés dans les chantiers Augustin Normand.

L'effort initial ayant été développé au profit de la Marine Militaire, les générateurs à pistons libres trouvent aujourd'hui des applications non seulement dans la Marine Marchande mais aussi dans d'autres domaines.

Ainsi, par exemple, l'usine de la S.I.G.M.A. exploite un groupe électrogène pour ses besoins; à l'usine de Reims d'Électricité de France, un compensateur synchrone est attelé à une turbine à gaz alimentée par un générateur à pistons libres; une locomotive de 1.000 ch utilisant la machine nouvelle et construite par la Régie Nationale des Usines Renault a parcouru 70.000 km avant novembre 1953; des groupes électrogènes fonctionnent à Détroit, à La Havane, à Gafsa.

Une ample et rapide expansion en France, dans ses territoires d'Outre-Mer et dans les pays associés ou étrangers, apparaît aujourd'hui très sérieusement prévisible.

La Marine Militaire a également été l'initiatrice, en France, des progrès des turbines à gaz composées de turbomachines. En outre de deux appareils moteurs expérimentaux de 10.000 ch, dont la construction fut confiée en 1938 respectivement à la Société Rateau et à la Compagnie Électromécanique, elle a puissamment aidé à la connaissance des problèmes fondamentaux en faisant construire par la Société Rateau plus de soixante groupes de suralimentation pour chaudières.

Ces machines sont de puissantes turbines à gaz qui ont prouvé leur robustesse au cours de nombreuses années d'exploitation. L'une d'elles équipée d'un foyer, sert de station de compression au Laboratoire déjà mentionné de la turbine à gaz.

Il faut aussi citer le groupe électrogène pour navire de ligne, conçu dès 1940, qui s'est transformé après-guerre en un groupe expérimental de 2.000 kW commandé à la Société Rateau. L'une des caractéristiques remarquables de ce groupe est la qualité de sa conception aérodynamique, laquelle s'est avérée plus avantageuse que les complications jugées souvent nécessaires: le rendement adiabatique interne du compresseur, mesuré au thermomètre et de bride à bride par la Marine, y dépasse franchement 89%.

La situation financière de la France, qui soumet encore le poids [illegible] ne permet plus à la Marine Militaire de financer seule les progrès des turbines à gaz composées de turbomachines.

Mais, plusieurs grands Services Publics, tels que la Direction du Matériel de la Marine Marchande et Électricité de France, ont su concilier la satisfaction de besoins immédiats avec une assistance aux constructeurs des machines dont l'avenir les intéresse. C'est ainsi que les Ateliers et Chantiers de Bretagne construisent, sous licence de la Société Rateau, un appareil moteur pour cargo qui effectue actuellement ses essais préliminaires en usine.

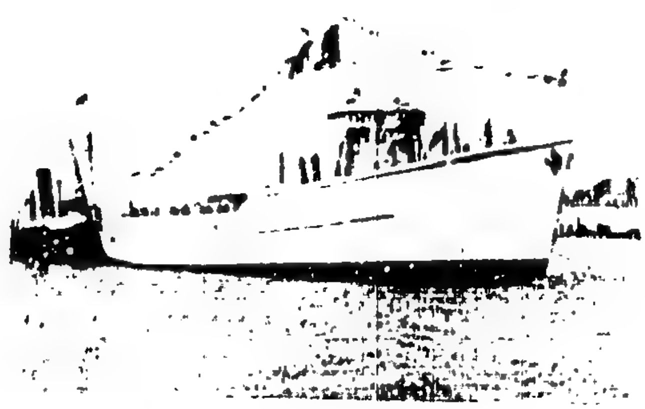

Fig. 5 — Dragueur de 1 [illegible] ch [illegible] à moteur « S.I.G.M.A. » — ALSTHOM.

De même, quatre groupes de 6 000 kW utilisables à l'injection de puissance électrique en extrémité de ligne par l'intermédiaire de compensateurs synchrones mis en route en période de pointe de consommation, ont été commandés par Électricité de France à la Société des Forges et Ateliers du Creusot, à la Compagnie Électromécanique, à la Société Rateau, à la Société S.I.G.M.A. La construction de la turbine du dernier groupe qui comprend des générateurs à pistons libres, est confiée à la Compagnie Électromécanique.

Enfin, il faut citer, comme ayant apporté une utile expérience d'emploi des turbines à gaz, les groupes de suralimentation construits par la Compagnie Électromécanique pour six chaudières Velox de cargos. Ces groupes assurent en effet, un véritable service industriel dans les conditions sévères de sécurité auxquelles sont astreintes les installations marines.

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LES APPLICATIONS

La rapide revue ci-dessus laisse déjà apercevoir le sens dans lequel les industriels français se proposent d'orienter leur action.

La Marine ouvre un large débouché aux turbines à gaz. Il existe une lacune qu'il s'agit de combler, entre les gammes de puissances réalisables par moteurs Diesel ou par turbines à vapeur. Les générateurs de gaz à pistons libres peuvent être multipliés pour produire une puissance supérieure à celle que peuvent fournir les plus gros Diesel. Les turbines à gaz composées de turbomachines s'accommodent du combustible employé pour les turbines à vapeur avec un rendement supérieur aux puissances moyennes. Pour les deux types, des avantages de poids, d'encombrement, de robustesse, de facilité d'installation et d'exploitation sont, en outre, à considérer.

L'emploi d'un moteur de locomotive composé de turbomachines a été envisagé naguère à plusieurs reprises. Il ne semble possible de retenir un tel projet que pour une machine de très forte puissance et destinée à franchir de longues étapes à allure et à puissance peu variables. Par contre, le générateur à pistons libres s'adapte avec souplesse à la traction ferroviaire. Les frais de première installation sont sensiblement inférieurs à ceux des locomotives Diesel-électrique grâce à la forme, pour la turbine motrice, de la loi de variation de son couple moteur avec la vitesse du récepteur, en particulier grâce à l'importance du couple de démarrage compatible avec un emploi avantageux d'une simple transmission mécanique.

Nous avons vu qu'Électricité de France a trouvé une utilisation intéressante des turbines à gaz à l'injection de puissance aux extrémités des lignes de distribution, en période de pointe, pour éviter la construction d'alternateurs. Un important programme à cet effet, comportant l'utilisation de groupes de 15.000 et de 20.000 kW, est en cours d'étude. Chaque ensemble restera simple, capable d'un rendement modeste mais suffisant, et comportera peu d'échangeurs.

L'expérience acquise permettra d'envisager la substitution des machines nouvelles aux moteurs Diesel des groupes électrogènes et aux turbines à vapeur de petites centrales électriques en France, dans les États associés ou à l'étranger, dans un domaine intermédiaire de puissance correspondant à peu près à celui qui est délimité pour la propulsion des navires. Dans ces applications particulières, les éléments favorables au choix d'une turbine à gaz peuvent être très divers: alimentation d'un petit centre industriel trop éloigné des grands pour qu'une interconnexion soit payante, difficultés d'adduction d'eau pour le refroidissement de condenseurs, frais excessifs de transport et de manutention de combustibles solides, proximité de champs pétrolifères ou de mines de charbon difficilement exploitables sans gazéification, indisponibilité de techniciens expérimentés et capables de conduire et entretenir des moteurs Diesel.

Enfin, la turbine à gaz est d'un emploi particulièrement indiqué [illegible] que et pour la manipulation de gaz divers. Sa constitution incorpore déjà des compresseurs alternatifs ou rotatifs, qu'il suffit de surdimensionner.

Le retard du développement des machines nouvelles constaté dans l'industrie sidérurgique, l'industrie chimique ou l'industrie du pétrole peut s'expliquer par plusieurs raisons: il n'existe pas dans ces industries de grands Services publics, au moins en France, en mesure de financer les groupes expérimentaux nécessaires; les ingénieurs de la profession ne sont pas essentiellement des mécaniciens et n'inclinent pas volontiers à être détournés de leurs préoccupations essentielles; l'équipement se renouvelle lentement et le choix de machines éprouvées, même surannées, garantit l'absence de soucis dans les quelques installations nouvelles.

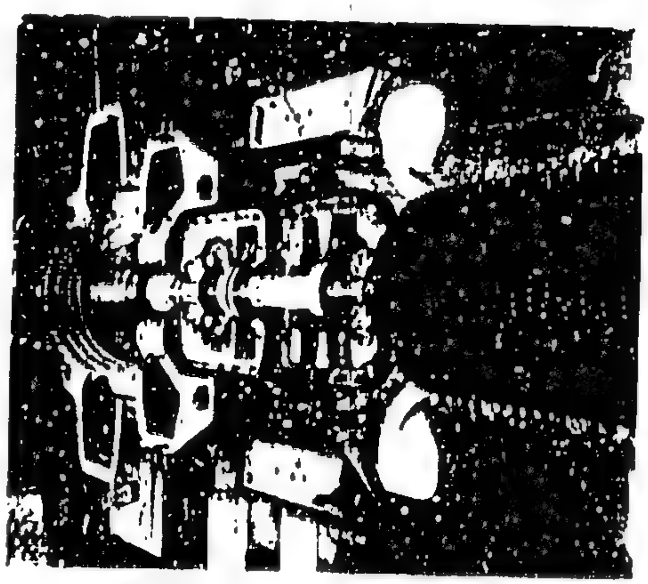

Fig. 6 — Groupe électrogène de 2 000 kW RATEAU alimenté par un foyer construit par l'Établissement National d'Indret

Cependant, aucune de ces raisons ne peut faire obstacle durablement au progrès de la technique, et on peut prévoir que des soufflantes de hauts-fourneaux et d'aciéries seront mises en construction au cours des prochaines années. Elles bénéficieront des recherches déjà exécutées pour la Marine, et n'occasionneront pas d'aléas si l'utilisateur et le constructeur demeurent ensemble assez raisonnables pour ne pas exiger d'emblée des machines nouvelles la totalisation des qualités diverses des machines anciennes.

En limitant ici l'énumération des applications, nous n'entendons pas écarter systématiquement certains usages particuliers, ni ignorer les recherches effectuées dans d'autres voies, soit en France soit dans d'autres

[illegible] nous pensons surtout, pour ce qui concerne le [illegible] gaz dans un cadre que d'aucuns peuvent trouver modeste mais qui est déjà fort large pour une machine dont les applications industrielles, fixes ou mobiles, ne font encore qu'à leur début. Il est clair, d'ailleurs, qu'un moteur de locomotive peut convenir parfaitement à un char d'assaut ou à d'autres engins comparables.

Dans l'ensemble, les domaines propres d'application des deux types de turbines à gaz passés ici en revue peuvent être assez bien schématisés comme suit. La machine alimentée par générateurs à pistons libres est directement comparable au moteur Diesel, et marque sur lui des avantages pour les puissances élevées, ou lorsque l'accouplement direct au

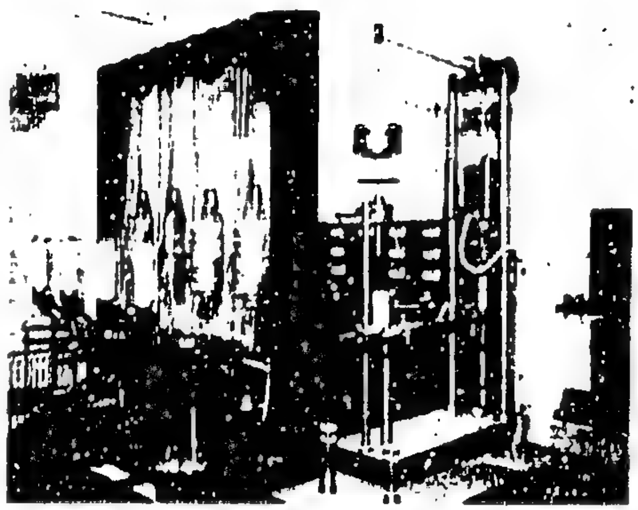

Fig. 7 — Batterie de machines de fluage aux Forges et Aciéries du Creusot.

récepteur de puissance n'est pas facile. Le groupe constitué de turbomachines est moins proche de la turbine à vapeur qu'on ne le pense parfois, mais peut lui être substitué dès qu'un rendement élevé est de peu de prix auprès du bénéfice de la simplicité, de la légèreté, de la compacité, enfin de la réduction des frais d'investissement et d'entretien.

LES MOYENS DE RECHERCHES

Chacun des principaux constructeurs français dispose en propre de moyens de recherche mais leur intérêt bien compris est de mettre en commun quelques moyens généraux d'exploitation onéreuse et d'échanger des informations techniques.

Les principaux constructeurs de turbines à vapeur marines et industrielles — dont certains consacrent aussi d'ailleurs, une part de leur activité à l'aéronautique — et les constructeurs de générateurs à pistons libres

et de moteurs Diesel se sont intéressés à la turbine à gaz. Avec les pou [illegible] navales, ils se sont groupés spontanément dans une Association Technique pour la turbine à gaz (A.T.T.A.G.), fondée en 1950 et à laquelle l'État a confié le soin d'exploiter un laboratoire créé par la Commission interministérielle déjà citée et dont la mission est de contribuer au progrès des études aérodynamiques intéressant la technique française des turbomachines. Cette Association organise de fréquentes réunions au cours desquelles sont posés et discutés les problèmes que les constructeurs n'ont pas la possibilité ou le loisir de traiter seuls. L'A.T.T.A.G. a déjà organisé en 1952 un colloque auquel étaient invités des confrères étrangers.

Les progrès de la turbine à gaz sont liés, non seulement à ceux de l'aérodynamique, mais à ceux des métaux réfractaires dont disposent les constructeurs. La sidérurgie française, grâce à l'équipement qu'elle a su, malgré les difficultés de l'époque, donner à ses laboratoires, à ses moyens d'élaboration, de forgeage et de traitement des métaux réfractaires, est aujourd'hui à même de contribuer activement aux nouveaux progrès actuellement à l'ordre du jour et de satisfaire les besoins des constructeurs. Ces derniers, lorsqu'ils ne contrôlent pas eux-mêmes une usine sidérurgique comme les Forges et Ateliers du Creusot, ont constitué et équipé de nouveaux laboratoires de qualification et de recherche sur les métaux, afin de collaborer plus étroitement avec leurs fournisseurs.

Grâce à leurs propres travaux, à leur action concertée, à leurs larges informations, aux contacts établis par certaines firmes avec l'étranger, les constructeurs français apparaissent aujourd'hui en mesure de fournir des machines à la fois sûres et à caractéristiques brillantes pour des applications bien choisies.

CONCLUSION

Dans ces dernières années et parce que, sans vanité prétentieuse, l'industrie française a été consciente de sa force, de son courage et de sa ténacité, elle a réalisé sans bruit, avec l'aide et l'appui éclairé de quelques grands Services Publics, des turbines à gaz bien équilibrées, bien adaptées à des besoins précis et qui constituent d'excellentes références. Elle peut aujourd'hui exploiter son effort et regarder au-delà des frontières du pays.

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Résumé

La France a réalisé au début de ce siècle la première turbine à gaz industrielle, et a repris son effort un instant suspendu. En fonction de considération économiques, ses constructeurs cherchent à remplacer les machines thermiques anciennes par les deux principaux types de turbines à gaz qu'ils ont développés: la turbine alimentée par un générateur à pistons libres, et la turbine composée uniquement de turbomachines. Les applications déjà trouvées sont rapidement énumérées et les voies d'expansion prévues sont indiquées. La fabrication de turbines à gaz est en France, dès maintenant, une branche industrielle appréciable, et son avenir est prometteur.

Summary

The first industrial gaz turbine was experienced in France who resume her effort delayed for a time. Taking into account economical factors, constructors try to substitute both principal types of gas turbines they have developped for conventional thermal engines. These types are: the turbine fed by a free piston generator and the turbine only consisting of turbomachines. Applications already found are briefly listed and ways of expansion are sketched. Gas turbine construction is already an interesting industrial branch and its future is full of prospects.

Resumo

No comêço dêste século, a França ensaiou a primeira turbina industrial a gás e agora volta a se ocupar dela, depois de interromper por algum tempo seu esfôrço. Em razão de considerações de ordem econômica, seus construtores procuram substituir as antigas máquinas térmicas pelos dois principais tipos de turbina a gás que desenvolveram: a turbina alimentada por um gerador de êmbolos livres, e a turbina composta ùnicamente de turbomáquinas.

As aplicações já encontradas são ràpidamente enumeradas e as vias de expansão previstas estão indicadas. A fabricação de turbinas a gás é na França, desde já, um ramo industrial apreciável e seu futuro promissor.

CONFERÊNCIA MUNDIAL DA ENERGIA
WORLD POWER CONFERENCE
REUNIÃO PARCIAL
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Rio de Janeiro — 1954

Título 1
Assunto 1.2

ROUSSELIER (M.)
França

L'INVENTAIRE TOTAL DES RESSOURCES HYDRAULIQUES COMME BASE DES PLANS GENERAUX DE DEVELOPPEMENT

Par M. ROUSSELIER
Directeur-Adjoint de l'ÉQUIPEMENT À L'ÉLECTRICITÉ DE FRANCE

COMITE NATIONAL FRANÇAIS

Le développement de l'équipement hydroélectrique apelle une prévision économique approfondie et une analyse plus fine de la rentabilité des projets dans les pays ayant mis en valeur une fraction importante de leurs disponibilités naturelles. L'héritage de l'insouciance relative du passé pèse déjà notablement sur les programmes actuels par mise en court-circuit prématurée d'usines anciennes, ou encore par des goulots de sous-équipement auxquels il est difficile de remédier. Les pertes d'énergie qui en résultent sont des fractions appréciables du productible nouveau.

Lorsque l'équipement d'un pays atteint l'âge de la maturité il apparaît ainsi illusoire, ou tout au moins insuffisant, de gagner péniblement quelques points de rendement sur les machines ou d'affiner les ouvrages de génie civil, si, parallèlement, des pertes économiques équivalentes, quoique moins visibles, doivent résulter d'un défaut de prévision sur la structure du système de production.

En d'autres termes l'art de la prévision économique doit désormais marcher de pair avec le souci de progrès technique, alors qu'il faut bien constater le peu d'estime dont il jouit chez les techniciens et le caractère extrêmement sommaire avec lequel il est souvent traité.

Les études économiques consistent à choisir les caractéristiques d'un projet de façon que leurs valeurs marginales soient en harmonie avec le système de référence choisi, autrement dit que ce projet ne contienne pas d'opération marginale (supplément de puissance, de réserve, etc...) plus chère que ce qui pourrait être fait ailleurs à la même époque. Elles consistent aussi à choisir la composition d'un programme de telle façon que le coût de l'énergie soit minimum pour un développement donné de la consommation garantie et un montant donné des investissements, ce qui fixe notamment la proportion hydraulique-thermique.

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Cependant, quel que soit le soin avec lequel on pousse les méthodes de comparaison, celles-ci ne sauraient trouver leur plein emploi sans une connaissance des caractéristiques techniques de la totalité du gisement hydraulique. L'ajustement de caractéristiques marginales sur des conditions momentanées, sans tenir compte des ressources les plus chères d'échéance plus lointaine, conduit à maintenir le sous-équipement tendanciel constaté jusqu'ici. D'autre part la composition optimum des programmes nécessite une connaissance étendue de la rentabilité des projets, et non seulement de ceux dont on dispose ou que l'on suppose à tort ou à raison être les plus rentables.

Il paraît donc superflu de justifier que les plans de développement de l'énergie hydraulique doivent s'entendre comme: "l'échelonnement optimum de la mise en valeur de la totalité d'un gisement hydraulique parfaitement défini dans ses caractéristiques techniques". Bien entendu un tel potentiel technique ne saurait être considéré comme absolument immuable, et doit être révisé périodiquement à mesure que des progrès de construction ou des rapports énergétiques nouveaux tendraient à le modifier.

Il semble que jusqu'ici on ait hésité à effectuer cet inventaire complet, autant par sous-estimation de l'intérêt des études économiques que devant l'importance de la tâche. L'objet du présent rapport est d'exposer les méthodes et résultats de l'inventaire physique et économique de l'ensemble du potentiel hydroélectrique français, et de donner un aperçu des possibilités d'exploitation de ce matériau de base dans l'ordre économique et technique.

Un tel inventaire n'est au surplus nullement prématuré si l'on songe que la croissance exponentielle de la consommation d'énergie électrique (malgré les incertitudes que l'on peut avoir sur son rythme) assigne des délais extrêmement brefs à l'épuisement des disponibilités naturelles des pays développés. Pour la France, qui a équipé 30% de ses ressources, il s'agirait de 20 à 25 ans sur la base du doublement en 10 ans et pour une proportion hydraulique thermique raisonnablement prévisible — mais il est remarquable qu'un tel délai serait à peine plus élevé pour un pays de mise en valeur sensiblement moins avancée, en raison du caractère exponentiel des lois de croissance.

I — MÉTHODE EMPLOYÉ

Les ressources des divers pays européens sont exprimées sous forme de statistiques incomplètes ne donnant généralement aucun renseignement sur la valeur des projets.

Un premier effort a été fait dans le rapport de l'E.C.E. des Nations Unies de Mai 1953: "Le potentiel hydroélectrique de l'Europe", pour exprimer le potentiel techniquement ou "économiquement" utilisable par corrélation à partir des données physiques du potentiel brut de ruis-

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seulement. Si cette étude donne vraisemblablement une première approximation [illegible] qu'elle se trouve limitée par la connaissance et la définition des données d'inventaire elles-mêmes qui constituent l'un des termes de la corrélation, l'autre terme (le potentiel brut) étant par contre défini et calculable. On ne saurait donc échapper à la méthode directe consistant à reprendre la prospection cohérente de projets concrètement définis, chacun étant evalué dans un même système de comparaison.

Tout en réservant pour la suite de l'exposé la nécessité de définitions precises de ces termes, la corrélation entre potentiel brut et potentiel technique ou économique semble rester assez lâche. Pour un certain nombre de bassins français on constate les chiffres suivants :

	Potentiel brut Milliards KWh	Production technique en % d'après E.D.F	Inventaire E.D.F. en %
Vienne, Creuse	1,59	18	30
Lot	10,61	35,9	35
Dordogne	15,33	27,1	11,6
Adour	16,22	27,1	36,6
Têt-Tech	2,83	12,4	10
Aude	2,75	19,5	18,6
Seine	8,4	5,1	33,5
Isère	35,21	31,6	48,3
Durance Verdon	18,5	33,1	45,8
Ensemble de la France	LCE 314	32 à 44 selon estimation	29
—	EDF 258	-	35

L'étude de telles corrélations reste indiscutablement intéressante à l'échelle d'un groupe de pays, ou encore pour évaluer les petites forces hydrauliques qui excèdent les possibilités pratiques d'une prospection projet par projet (on observera que les faibles pourcentages de zones de plaine comme la Seine sont dûs, en partie, au seuil de taille des aménagements inventoriées). Nous en retenons donc les possibilités comme consécutives à un inventaire qu'elles ne sauraient précéder

Critère de valeur

Le choix d'un critere de valeur ne peut s'établir que sur une théorie suffisamment complète, developpée dans la brochure "Détermination du critère de valeur d'un equipement" publiée par ELECTRICITÉ DE FRANCE. Cette théorie admet que trois criteres sont suffisants pour définir le coefficient de forme de la production hydraulique, soit :

1.°) La productibilite annuelle moyenne;

2.°) La puissance garantie des 1200 heures pleines d'un hiver sec critique (1948-1949);

3.°) La puissance de pointe disponible pendant deux heures par jour en hiver sec;

et pour la comparer à un système de référence composé de thermique de base et de thermique de pointe.

Les indications sommaires qui suivent, suffisantes pour l'intelligence du texte, se bornent cependant à l'emploi des deux premiers criterium en négligeant le troisième; simplification jugée préférable à l'échelle de l'inventaire et se justifiant par le fait que la satisfaction du criterium de puissance garantie entraîne approximativement celle du criterium de pointe ou de plus grande puissance appelée sur le réseau.

Nous comparons donc le projet hydraulique à un système thermique de référence de même puissance garantie, et le caractérisons par le

critère de valeur $V = \dfrac{E}{d} + 1$:

d représentant les investissements du projet considéré,

$E = (e - d) - (e_o - d_o)$ représentant le bénéfice actualisé ou enrichissement relatif exprimé en capital par rapport au thermique de référence d'indice o. Les termes e du bilan représentent l'économie de charbon actualisée sur le système existant, moins les charges d'exploitation et de renouvellement actualisées c'est-à-dire exprimées en capital. Il est en outre tenu compte des charges de transport.

L'enrichissement relatif en capital par franc investi est donc $V - 1$; il est assimilable à un taux de rentabilité relative par rapport au thermique. La limite économique d'une chute, dans les conditions actuelles, correspond ainsi à un taux nul ou encore à $V = 1$: au-dessous de ce seuil on a théoriquement intérêt à équiper du thermique.

Choix du seuil de valeur

On est amené bien entendu à faire choix d'un seuil inférieur à $V = 1$ pour explorer le potentiel technique au-delà des limites actuellement admises. Il faut avoir présent à l'esprit que le mot de potentiel économique n'a de sens que relativement à un seuil V_o et comporte tous les projets de $V \geq V_o$. Nous avons choisi finalement le seuil minimum $V_o = 0{,}6$ pour les raisons suivantes:

1°) V est fonction des taux d'intérêt et d'actualisation pour lesquels nous admettons actuellement 6 % et 8 % respectivement. Si l'on admet que ces taux pourraient s'abaisser jusqu'à 2,5 % dans une conjoncture ultérieure favorable aux investissements, la limite $V = 1$ correspondrait alors sensiblement à $V = 0{,}6$ dans la conjoncture actuelle.

2°) Il faut tenir compte de la précision de la méthode. Elle comporte [illegible] 20%, provenant pour la plus grande part des erreurs d'appréciation sur les projets d'inventaire fondés sur des études préliminaires, et bien entendu de celles qui affectent les éléments de comparaison (autrement dit les constantes) entrant dans le coefficient de valeur.

3°) Bien qu'il soit difficile de deviner le sens dans lequel s'exercerait l'évolution des prix relatifs des ouvrages de génie civil, des générateurs thermiques, du charbon, etc (nous reviendrons un peu plus loin sur cette importante objection de la distorsion des valeurs dans le temps), certaines évolutions techniques prévisibles militent en faveur d'un seuil assez bas. C'est le cas des basses et très basses chutes qui se rangent dans les chutes les plus médiocres avec des évaluations basées sur la technique actuelle. C'est aussi le cas des réservoirs où digues et rideaux étanches. profonds ouvrent des perspectives nouvelles ou plus économiques. Citons encore le développement de l'automatisme et son effet relatif important sur les charges d'exploitation des petites installations.

Ces considérations font sentir certaines difficultés de principe dans l'emploi du critère de valeur, lorsqu'il ne s'agit plus d'un projet isolé considéré comme marginal vis-à-vis du système de production existant, mais d'une suite de projets représentant plusieurs fois ce système et s'échelonnant sur des dizaines d'années.

L'une résulte de l'influence réciproque des projets, par exemple un réservoir influençant une chute au fil de l'eau située à l'aval. La valeur individuelle des projets dépend de l'ordre d'exécution, ou d'une réparches profonds ouvrent des perspectives nouvelles ou plus économiques. Il faut donc soit opérer par approximations successives si l'on admet que l'ordre d'exécution est rigoureusement à V décroissant, soit admettre une distorsion individuelle qui est sans conséquence sur la courbe monotone totale du potentiel en fonction de V, ou sur le V moyen du bassin.

L'autre provient de ce que les caractéristiques des projets répondent actuellement à des valeurs marginales V ≈ 1 ce que traduisent soit l'expérience du projeteur, soit les abaques de détermination simplifiée des caractéristiques. L'équipement des projets tend à s'accroître pour des valeurs marginales plus basses, d'où une certaine sous-estimation du potentiel. Nous avons pu nous assurer en nous basant sur quelques projets actuels au fil de l'eau que la correction était faible sur le productible (de 2 à 6%), mais pourrait être beaucoup plus forte sur le taux des réserves et la puissance garantie, ce que nous n'avons pas les moyens d'évaluer à ce premier stade de travail.

Une troisième objection résulte de l'évolution non prévisible des constantes du coefficient de valeur dans l'avenir. Observons que ces constantes intègrent déjà les éléments prévisibles: par exemple l'économie de charbon comprend une économie permanente correspondant à la consommation spécifique limite des thermiques nouvelles, et une économie tran-

[illegible] fonction du déclassement des thermiques anciennes à consomma[illegible]. Nous pouvons cependant négliger dans nos calculs les éléments non prévisibles qui, du fait de l'actualisation, n'ont en valeur actuelle qu'un poids bien inférieur à l'erreur probable sur le coefficient V : tels seraient par exemple les modifications résultant d'une baisse du rapport hydraulique thermique dans une vingtaine d'années, en raison de l'épuisement relatif de l'hydraulique.

Il en va tout autrement si, au lieu de considérer le V de l'époque actuelle, nous considérons celui qu'aurait le projet à l'époque de sa réalisation, le jeu de l'actualisation pour cette époque ne permettant plus de négliger les modifications des constantes. Le calcul de ces modifications est possible moyennant certaines hypothèses de développement, nécessitant d'ailleurs une idée préalable sur l'étendue du gisement hydraulique où se borne l'étape actuelle de notre travail. Les résultats économiques du présent inventaire, établis en valeurs actuelles, comportent donc une certaine distorsion qui croît avec le temps (ou encore avec le rang décroissant des valeurs), et qui relève d'une étude de seconde étape. On observera que cette distorsion répond très vraisemblablement à une sous-estimation des valeurs les plus faibles, car on est fondé à penser que celles-ci se situent dans une proportion hydraulique/thermique plus basse. Il lui correspondrait un relèvement de la queue de l'inventaire, et on trouvera là une nouvelle justification du choix d'un seuil de valeur assez bas.

Seuil de taille

On a été amené, pour alléger la tâche matérielle, à éliminer en principe les projets inférieurs à 5 à 10 Millions kWh, l'appréciation entre ces deux chiffres étant à la charge du projeteur (situation, facilités d'accès, de raccordement au réseau, de télécommande ou d'automatisme... etc.). Cependant les petites ressources hydrauliques constituent un appoint non négligeable de plusieurs milliards de kWh, exclu du présent inventaire. Certaines considérations(1) nous conduisent à penser que la "taille économique" diminue avec la puissance linéaire brute du cours d'eau. Autrement dit, sans donner naturellement à cette affirmation un caractère absolu, les petites tailles que permet l'automatisme permettent théoriquement l'équipement économique de zones jugées classiquement sans intérêt. Ce fait est illustré par les microcentrales de très basses chutes (1 m 50 à 2 m) qui, pour une puissance permanente de 50 à 100 kW, ont un V voisin de 1.

L'inventaire des petites forces hydrauliques n'offrait pas pour l'instant un intérêt en rapport avec l'effort de prospection. Nous en donnons

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(1) Rapport à la [illegible] Conférence Mondiale de l'Énergie "Considérations sur la taille des équipements".

cependant hors inventaire une estimation provisoire approximative basée [illegible] témoins, étant entendu qu'elle ferait l'objet d'une étude spéciale ultérieure.

Le rôle fonctionnel des petites forces hydrauliques dans la structure du réseau, en dehors de l'appoint énergétique qu'elles représentent, consiste à réduire le coût de développement des réseaux de distribution et de répartition en raison de leur situation générale en bout de ligne. En intégrant les charges de réseau (alors que le coefficient V ne tient compte que du grand transport) on peut en certains cas doubler par exemple le coefficient de valeur des petites opérations, en soulageant une fraction des réseaux d'une capacité égale à leur contribution à la pointe.

Travaux de prospection et d'évaluation

Les travaux de prospection ont été répartis par Régions entre une douzaine de projeteurs et appuyés sur des reconnaissances de terrain. Ceux-ci disposaient dans l'ensemble d'une bonne infrastructure de stations de jaugeage et de profils en long des rivières; là où cette infrastructure était insuffisante (ancienne carte de France au 1/80.000) le travail s'est naturellement avéré plus long et difficile et a comporté l'emploi de moyens topographiques expédiés (altimètre, télémètre... etc.).

L'emploi d'un matériel assez complet d'abaques pour études préliminaires a permis non seulement de réduire considérablement les calculs d'évaluation mais encore de diminuer les écarts systématiques dûs à "l'équation personnelle" des projeteurs.

La durée des travaux s'est étendue sur un an mais avec des intermittences notables.

Il peut être intéressant d'en donner le coût très approximatif. En défalquant 21 000 GWh d'études en cours à des stades divers qui ont été simplement intégrées dans l'inventaire, le coût moyen par projet est de 30.000 Fr pour quelque 600 projets nouveaux ou remaniés, ou encore de 0 Fr 50 par million de kWh au inventorié, ce qui est extrêmement faible et correspond à un taux d'études rapporté aux investissements de 0,01%.

Il faut bien entendu tenir compte de ce que des sommes plusieurs fois supérieures avaient été dépensées antérieurement, de façon directe ou indirecte, au titre de l'infrastructure géohydrologique, l'inventaire n'étant par ailleurs qu'un premier dégrossissage aux incertitudes accidentelles encore assez fortes.

II - RÉSULTATS

Les résultats globaux sont les suivants, y compris ceux correspondant à un seuil intermédiaire de 0,8 :

	Productibilité (GWh)	Puissance garantie MW	Puissance installée MW
Usines en service fin 1955	27 000	3 570	7 100
Usines inventoriées $V \geqslant 0,8$	51 000	8 700	12 900
Usines inventoriées $V \geqslant 0,6$ . .	64 200	10 200	16 200

y compris un faible résidu inférieur à 0,6 (3.000 GWh)

La figure 1 donne la courbe monotone du potentiel inventorié en fonction de V pour l'ensemble de la France. Les courbes en trait mixte représentent l'extrapolation probable du potentiel pour des valeurs très faibles, et situent très approximativement les limites extrêmes du "potentiel technique". L'ensemble des disponibilités hydrauliques françaises pourrait ainsi être évalué à 92 000 GWh, marémotrices non comprises, alors que la statistique officielle donne un chiffre de 70.000 GWh.

La répartition de la productibilité des projets en fonction de marges de valeur de 0,2 correspondant en gros à la précision de la méthode, est la suivante :

V	$\geqslant 1,6$	1,6 1,4	1,4 1,2	1,2 1,0	1,0 0,8	0,8 0,6	$< 0,6$
Productibilité milliards kWh	5,77	10,13	12,11	10,63	11,06	10,14	3,0

La figure 2 donne les coûts classés du kW installé et du kWh.an qui répondent à des notions plus courantes que celle du critère V, mais n'ont d'intérêt qu'en séparant les catégories de projets : lac, écluse, fil de l'eau

Critiques et précision des résultats

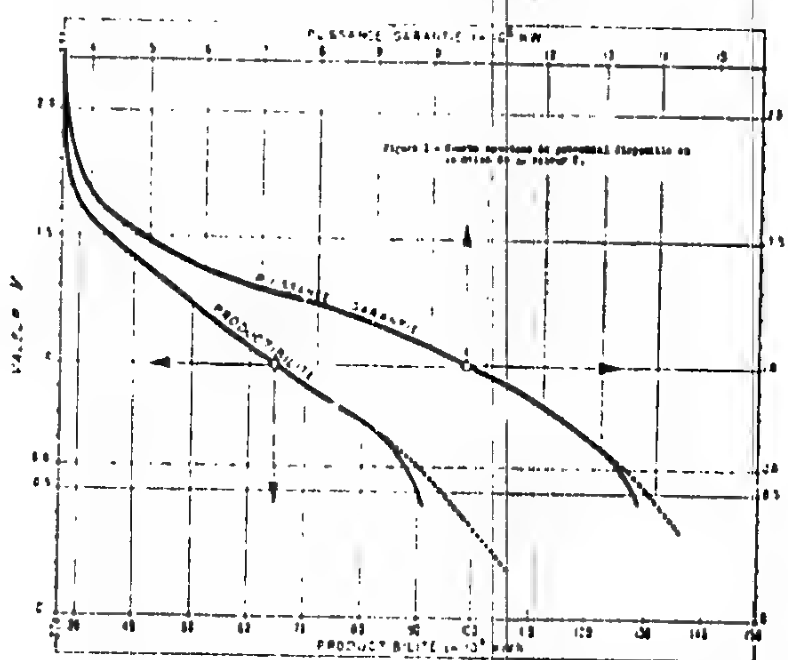
Ceux-ci sont naturellement moins précis dans l'ordre économique que sur le plan énergétique. Nous admettons, sans en développer ici les raisons, qu'un potentiel (V_0) s'entend pour $V_0 \pm 0,1$.

Pour l'énergie disponible on doit pouvoir escompter une précision [illegible] compensation opérée sur un grand nombre de projets. Mais d'autres corrections jouent dans des sens systématiques opposés.

La surestimation la plus importante provient d'une appréciation généralement optimiste des débits réservés, et d'une optique trop purement énergétique ne faisant pas une part suffisante aux projets à fins multiples et aux besoins d'irrigation et d'alimentation en eau (il est vrai qu'en revanche les projets à fins multiples peuvent dégager certaines quantités d'énergie, qui, prises isolément, tomberaient au-dessous du seuil de rentabilité). En outre on peut envisager certaines servitudes touristiques irréductibles, ainsi que des aléas géologiques majeurs non décelés qui auraient pour effet de rendre soit le projet pratiquement irréalisable, soit de le faire tomber au-dessous de la fourchette $V_s - 0{,}1$ précédemment admise.

Il y a en revanche un certain nombre de sous-estimations dont nous pouvons avoir un assez bon ordre de grandeur :

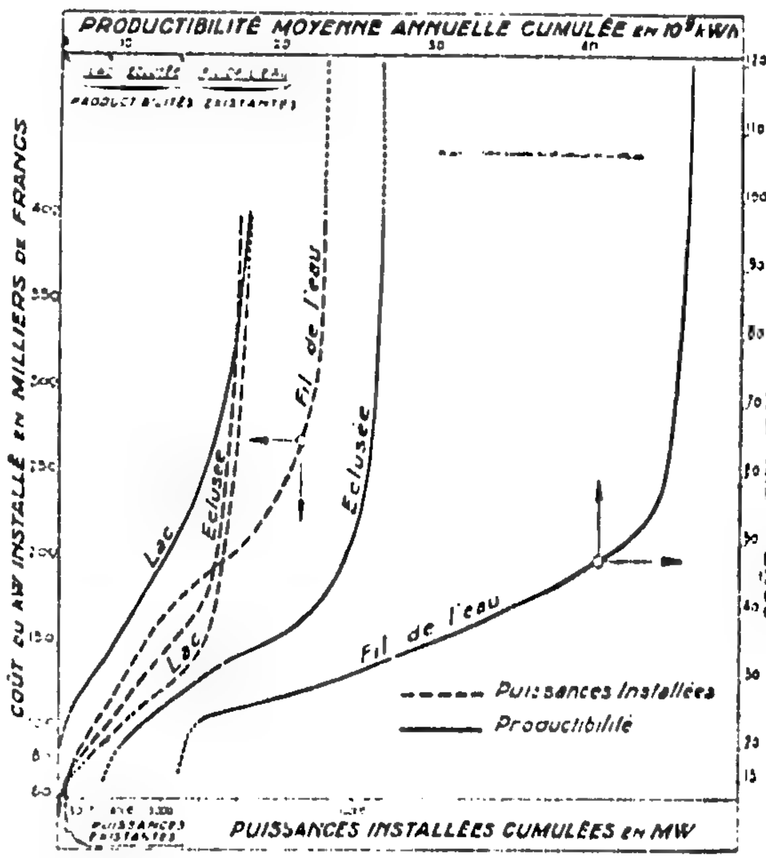
- la correction de caractéristiques marginales déjà citée doit donner 1.000 GWh.
- les opérations de suréquipement d'usines en service, généralement omises, et les majorations de rendement par renouvellement (3 000 GWh).



— les petites forces hydrauliques inférieures à 2 MW de puissance [illegible] estimer par différents recoupements (2) à 12.000 GWh.

— Enfin certaines zones révèlent des lacunes de prospection que nous n'avons pas eu le temps matériel de combler.

Au total, s'il est difficile d'affirmer qu'il y ait compensation, on peut admettre que les donnés brutes précédentes peuvent être retenues avec une certaine prudence comme valeur probable, ou encore que les disponibilités nouvelles sont comprises avec une assez forte probabilité entre 60.000 et 70.000 GWh, moyennant une certaine tolérance sur le seuil de valeur.



(2) Extrapolation de la courbe monotone potentiel-taille au-dessous de 2 KW; hypothèse d'une représentation de fréquence identique à celle des installations existantes; enfin évaluation des densités de production par km² réalisables comme résultat de l'inventaire sur certains bassins caractéristiques.

Il est normal qu'une prospection attentive recule les limites du po- [illegible] estimations dépassent sensiblement celles des études antérieures.

Nous évaluerons en définitive les disponibilités totales inventoriées à:

60 – 65 milliards kWh pour V_o 1
75 – 80 milliards kWh pour V_o 0,8
85 – 95 milliards kWh pour V_o 0,6

et compte tenu des petites forces hydrauliques à :

100 milliards kWh en chiffres ronds

en donnant à ces dernières une valeur probable de la moitié de leur estimation théorique.

Potentiel technique

Il est bon à cette occasion de se débarasser d'un mythe en montrant que le potentiel technique échappe en réalité à toute définition : Il n'est d'autre notion possible que celle de potentiel économique pour un seuil de valeur donné. Supposons en effet, que l'on veuille définir ce potentiel technique comme celui qui est pratiquement réalisable "sans considération de prix de revient". On constaterait aisément que V tend asymptotiquement vers une valeur limite légèrement négative, de l'ordre de –0,2, lorsque le coût croît indéfiniment (cette limite n'est autre que le taux actualisé des charges proportionnelles aux investissements). Le potentiel économique se raccorde ainsi à une limite théorique de l'ordre de 70 à 80 % du potentiel brut de ruissellement, sans autre frontière que celle du sentiment de l'absurde.

Si l'on tenait, malgré le faible intérêt de cette spéculation, à définir tout à fait arbitrairement le potentiel technique par $V_o = 0$ par exemple (ce qui correspond en gros à cinq fois le coût actuel pour l'équivalence thermique) on aboutirait par une extrapolation hasardeuse à quelque 110 milliards de kWh.

III – PERSPECTIVES D'EXPLOITATION DE L'INVENTAIRE

Ces perspectives ne seront qu'ébauchées, chacune d'elles représentant une étude particulière qui justifierait une reprise plus approfondie de l'inventaire. Celui-ci constitue une matière première essentielle de la planification, concernant non seulement les plans de développement de l'énergie électrique et des industries de construction qui lui sont rattachées, mais encore les plans généraux d'aménagement du territoire par la localisation des densités de production et l'évolution probable du coût de l'énergie électrique dans le temps.

1°) Sélection des programmes

En première approximation la sélection des projets doit théoriquement s'appuyer sur le rang des V décroissants (3). En fait il ne peut en être exactement ainsi car l'étendue insuffisante du portefeuille d'études et différentes opportunités introduisent certaines contingences.

L'effet de prévision est illustré par le fait que le premier programme hydraulique français (1947 - 1953) se trouve être d'une rentabilité inférieure à celle du deuxième programme envisagé, le V moyen passant approximativement de 1 à 1,3 (une partie de cet écart provenant toutefois d'une conjoncture concurrentielle plus favorable diminuant le coût probable des travaux du second). Or le bénéfice actualisé résultant de la permutation de deux opérations équivalentes dont les V respectifs sont d'ordre croissant dans le temps peut être important en valeur relative : par exemple pour V = 1 et 1,3 distants de 6 ans, il est de 21 % de l'enrichissement relatif du second, soit de 21 % × 0,30 = 0,06 Fr par franc investi (ou si l'on veut pour 2 Fr investis sur l'ensemble). L'expérience nous montre constamment des interversions avec des écarts très supérieurs, sinon en valeur, du moins en durée, ce qui confirme l'importance économique de l'effet de prévision évoquée dans l'introduction.

Comme on ne saurait s'aligner sur une décroissance rigoureuse, on ne peut naturellement affirmer que nos programmes futurs comporteront un V moyen de 1,55 pour 22 000 GWh puis de 1,30 pour 18 900 GWh, etc., comme il résulterait de la courbe monotone. Mais on peut considérer que (même avec une certaine erreur systématique d'optimisme sur l'inventaire) la "loi du rendement décroissant" ne jouera, à l'échelle des programmes, que dans un délai relativement éloigné correspondant en gros à la mise en valeur de la moitié du potentiel total.

On pourrait même escompter au début de cette période un léger relèvement de valeur analogue à celui constaté entre nos premier et deuxième programmes, bien que le bénéfice relatif de la sélection très important au départ, tende par la suite, à s'amenuiser (4).

Cette atténuation de la décroissance de la valeur dans le temps, qui accroît en quelque sorte, par un phénomène de dispersion des programmes, les limites d'un potentiel économique V_e, incite donc à dépasser le

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(3) La limitation des investissements pour un développement donné de la consommation conduit en fait à envisager l'ordre décroissant de $\frac{1}{d - d_u}$ les symboles ayant les significations indiquées au chapitre 3.

(4) Un autre effet de la sélection élargie, dû aussi à la normalisation des caractéristiques marginales, est la réduction de la dispersion des valeurs des projets d'un même programme. L'écart type passe de 31 % du coût moyen dans le premier programme à 20 à 27 % dans les programmes nouveaux, et pourrait être encore atténué si certaines contingences extra économiques ne pesaient sur leur composition.

cadre élémentaire de la courbe monotone et à se livrer à des spéculations [...] en valeur. Pour celles-ci le bon sens conduit à admettre que la loi exponentielle doit être corrigée (sans doute vers les 2/3 du potentiel total) de façon à se raccorder par inflexion à une courbe en S, d'ailleurs conforme à toutes les lois de développement économiques ou naturelles connues. La figure 3 donne un schéma indicatif des baisses de valeur, avec l'hypothèse d'un taux de croissance de 7,2% par an et d'une proportion constante de 60% d'hydraulique jusqu'au point d'inflexion. L'étude effective serait beaucoup plus complexe puisqu'elle devrait faire intervenir, outre diverses spéculations, la distorsion des constantes du coefficient V à mesure que change la structure du système de production.

Retenons qu'une caractéristique intéressante d'un gisement hydraulique est sa valeur moyenne (égale ici à 1,1), et que les gisements pourraient s'exprimer plus aisément dans des statistiques internationales par quelques caractéristiques numériques bien choisies au lieu de courbes monotones (comme sont exprimées les caractéristiques d'un régime de débit par exemple).

2°) *Coefficient de forme*

Il est intéressant de vérifier dans quelle mesure les ressources nouvelles permettent de satisfaire la courbe de demande avec une proportion convenable de thermique. En abandonnant, nous avons dit pourquoi, le

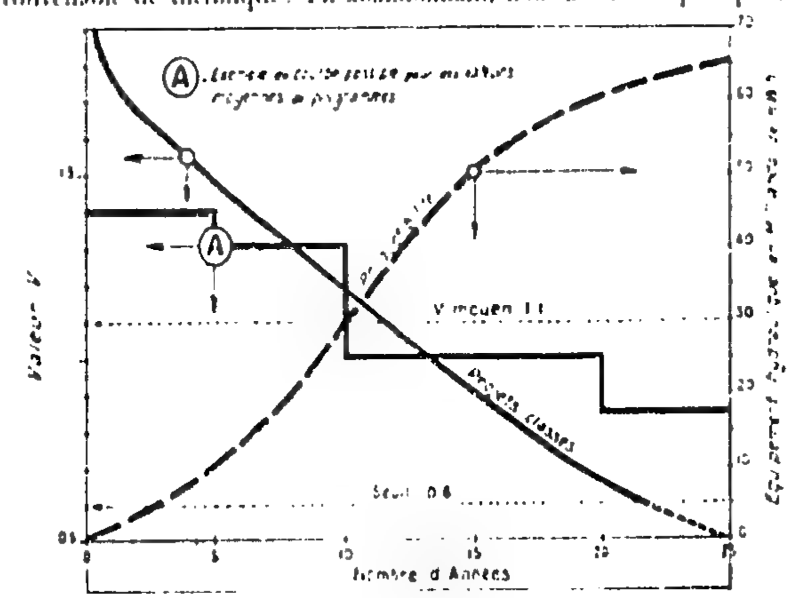

Fig. 3 — Evolution de V en fonction du temps. Figuration des "lois de rendement décroissant" de l'équipement.

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critère de contribution à la pointe, mais en admettant que la puissance installée est en rapport constant avec celle-ci pour des tranches d'échelle suffisante, la comparaison suivante fait ressortir une forte similitude entre l'inventaire et le système hydraulique actuel :

	Système existant	Inventaire
Productibilité (milliard KWh)	27,7	64,2
Puissance normale disponible PND (GW)	3,16	7,2
Puissance installée PI (GW)	7,4	16,2
Puissance garantie Pg (GW)	3,7	10,2
Rapport Pg/PND	1,07	1,4
Rapport PI/PND	2,3	2,2
Répartition par régime:		
Alpes	56%	65%
Massif Central	25%	23%
Pyrénées	19%	12%
Taux des réserves	13%	15%

La proportion d'hydraulique étant actuellement de 53%, semble pouvoir être portée à 60% environ en raison de l'augmentation de la proportion de puissance garantie, ce qui définit la taille maximum du réseau français au-delà de laquelle il faudrait de toutes façons envisager un développement entièrement thermique ou faisant appel à d'autres formes d'énergie: 150 Milliards KWh environ.

Le graphique de l'énergie mensuelle *moyenne* au fil de l'eau (figure 4) fait ressortir l'accentuation de la prépondérance du caractère alpin vis-à-vis de la situation actuelle, le déstockage des réservoirs pouvant fournir un complément reportable de 13 Milliards KWh.

La méthode statistique exposée par M. HALPHEN dans "Le Problème du Plan pour l'Équipement Électrique Français" pourrait trouver ici un large champ d'application pour les prévisions à long terme, en retouchant sur des données concrètes les "poids" des différents régimes hydrologiques.

3°) *Orientation des Études*

Il va de soi que la possession de structures complètes, fussent-elles à l'état d'ébauche, permet d'éviter dans une grande mesure les erreurs de prévision sur les interférences de bassins, sur le choix des débits d'équipement, qui pourront être adaptés aux conséquences les plus lointaines,

enfin sur les modifications apportées aux usines en service a le favent [illegible] peut souvent, pour un coût minime, amorcer de futures extensions.

L'idée s'impose donc de découper le potentiel en tranches d'avant-programmes et d'orienter les études en conséquence. S'il faut relativement peu de temps pour établir les plans d'un ouvrage une fois le terrain reconnu, le temps est très peu réductible pour la préparation des

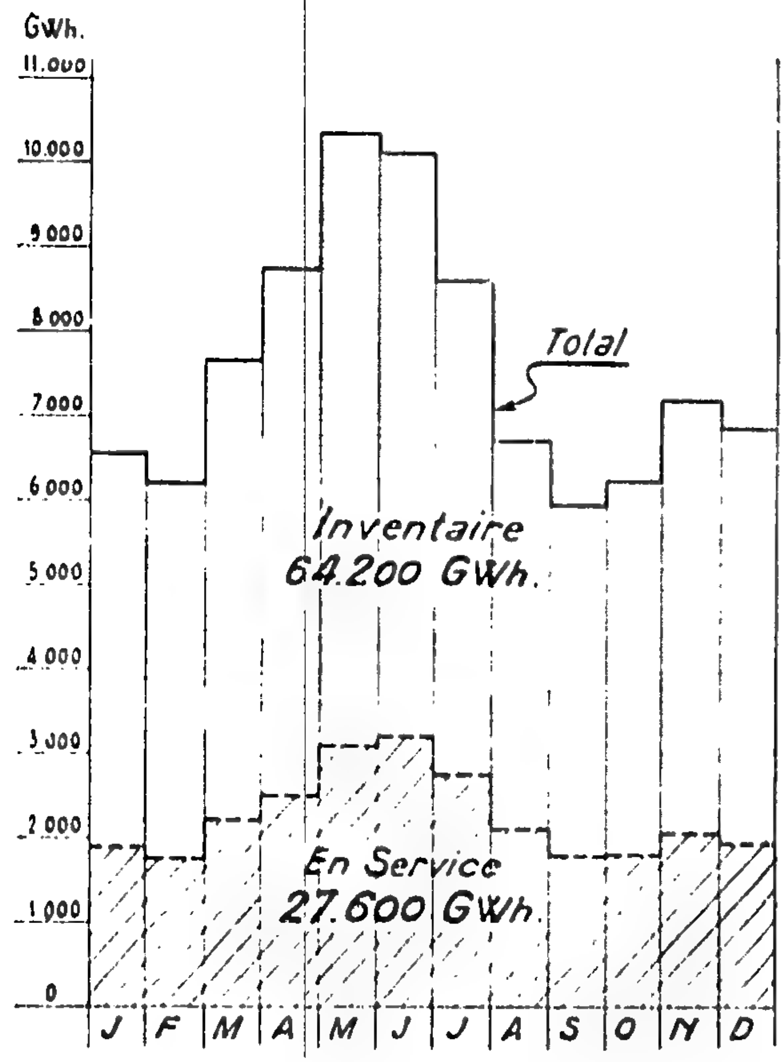

Fig. 4 — Energie moyenne mensuelle disponible au fil de l'eau.

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[illegible] topographique, observations de débits re[illegible] souvent pour l'instruction administrative [illegible]

Les avant-programmes donnent la base d'une organisation rationnelle des études consistant à démarrer en temps voulu ce qui est strictement nécessaire, sans pour autant aborder des projets d'exécution qui nécessitent un personnel spécialisé et s'accommodent mal de suites de temps morts ou sont remises en cause les caractéristiques essentielles.

La répartition par Régions naturelles renseigne sur l'intérêt et le volume des projets et sur leurs échéances d'avenir, et peut ainsi infléchir notablement l'orientation des études et même l'organisation de services d'équipement.

On peut par exemple remarquer immédiatement le grand intérêt du Rhin, des Cévennes, de la Durance et de l'Isère, l'avenir restreint des Pyrénées dont la grosse tranche médiane est au surplus frappée d'aléas; la Zone Nord a orienter vers les petites forces hydrauliques, etc ...

Un autre domaine d'orientation porte sur le transport. Si l'on ne peut mieux faire que de supposer un développement de la consommation proportionnel à la répartition actuelle, on peut par contre supputer les délais de développement et d'épuisement des ressources hydrauliques pour chaque région, et en tirer des conséquences sur l'importance et le sens des courants d'échange. En particulier le sens général sud-nord au moment de la pointe aura tendance à diminuer puis à s'inverser à partir de l'infléchissement probable de la proportion d'hydraulique, soit dans un délai relativement bref (fig. 3). Enfin il va sans dire que la prévision de la structure de production est d'une grande importance pour les structures des réseaux de répartition et même de distribution.

Iº) Conséquences techniques

D'une façon générale l'inventaire ouvre des perspectives techniques multiples par le fait qu'il situe l'importance et la nature des problèmes à résoudre. Citons-en rapidement quelques uns :

- l'importance du potentiel du domaine à peu près inexploré des très basses chutes inférieures à 6 m. peut dégager l'intérêt de s'attacher techniquement au problème et de consentir les dépenses de recherches pour des groupes économiques de type axial ou autres, comme c'est actuellement le cas pour les usines marémotrices.
- l'importance des disponibilités en microcentrales justifie l'étude de groupes standardisés et l'appréciation de leur influence sur la capacité de pointe des réseaux de distribution.
- l'exploitation purement statistique des matériels hydrauliques peut suggérer des standardisations qui seraient sans intérêt sur des perspectives plus limitées. Les ouvrages de génie civil eux-mêmes, soit

TABLEAU DES REPARTITIONS PAR REGIONS NATURELLES

REGIONS	Potentiel inventorié (Milliards kWh)				OBSERVATIONS
	V > 1,2	1,2 ≥ V ≥ 0,8	V < 0,8	Total	
1 — RHIN	4,6	—	—	4,6	V > 1,2
2 — *Zone NORD* (au nord ligne NANTES-BELFORT)	0,12	0,38	0,11	0,65	Incomplet sur petites chutes
3 — *CEVENNES*	2,4	0,5	0,18	3,08	Dérivation du versant atlantique sur le RHONE.
4 — *MASSIF CENTRAL* (LOIRE, DORDOGNE, affluents R.D. de la GARONNE	4,4	5,1	1,5	11,00	
5 — *PYRENEES & GARONNE* jusqu'au confluent du TARN	4,4	1,1	1,8	7,26	
6 — *JURA*	0,5	0,28	0,5	1,27	
7 — *ARVE et affluents du Haut RHONE*	0,7	0,76	0,8	2,30	
8 — *ISERE*	6,1	2,6	1,1	9,81	
9 — *DURANCE & FLEUVES côtiers*	7,0	4,2	2,0	13,20	
10 — *RHONE*	2,7	6,0	2,1	10,84	Inventaire très poussé. Données économiques très approximatives.

par leurs caractéristiques soit par la nature des sites à aménager, peu[illegible] des matériels de chantier, ou, si l'on préfère, donner par un groupage rationnel le gain de productivité obtenu ailleurs par une rotation accélérée sur des travaux de gros volume. Bien entendu ces spéculations n'ont de sens, et ne pourraient intéresser les industries de construction, que dans l'optique d'une continuité du rythme d'équipement.

La fécondité de l'exploitation statistique s'exprime assez bien sur deux points particuliers que nous ne pouvons qu'effleurer ici.

La répartition de la taille des centrales (soit la puissance installée), sur le polygone de fréquence de la figure 5 tracé en coordonnées logarithmiques, exprime nettement que les centrales en service se groupent en deux ensembles distincts, correspondant aux tailles supérieures et inférieures à 1 MW, et obéissant à la même loi de répartition. La raison de deux ensembles, qui ne répond à aucune réalité physique (c'est-à-dire orohydrologique), doit être probablement recherchée dans les règles administratives, l'usage public ou autonome de l'énergie, la composition du capital, qui consacrent les différences entre grand équipement et petit équipement, ce dernier allant du moulin à la petite industrie locale. Le nombre approximatif des installations est de 3 500 entre 10 kW et 300 kW, de 100 entre 300 kW et 1 MW, et de 500 au-dessus de 1 MW.

L'inventaire limité au grand équipement obéit à la même loi de répartition que les deux ensembles précédents. Pour 877 projets inventoriés au-dessus de 2 MW, la taille moyenne est de 20 MW, très voisine de celle du grand équipement en service (23 MW). Les disponibilités nouvelles ont donc une similitude de structure remarquable avec les disponibilités actuelles, confirmant ainsi que l'avenir n'apportera pas d'accroissement sensible de la taille des installations, tant il est vrai que le "terrain commande", c'est-à-dire que les conditions humaines et orohydrographiques commandent. Ceci souligne l'intérêt d'un développement massif de la télécommande et de l'automatisme, dont le rendement est en raison inverse de la taille, et dont la conséquence pratique est la prévision des groupements télécommandés et des centrales pilote dans l'étude des aménagements. La normalisation des dispositions-type des centrales, allégeant les études et rationalisant l'exploitation, paraît également une règle d'économie absolue pour les petites unités, règle dont la validité peut s'étendre jusqu'à une fréquence suffisante.

Les figures 6 et 7 tentent de dégager une corrélation entre la taille et la valeur des projets et expriment de deux façons différentes une croissance très nette de la valeur avec la taille. Les petits projets sont sensiblement moins économiques, encore que cette impression soit à corriger d'une mauvaise appréciation de leurs charges d'exploitation due à une expérience trop courte des petites installations modernes à haut degré d'automatisme, et aussi d'une appréciation trop élémentaire des charges de

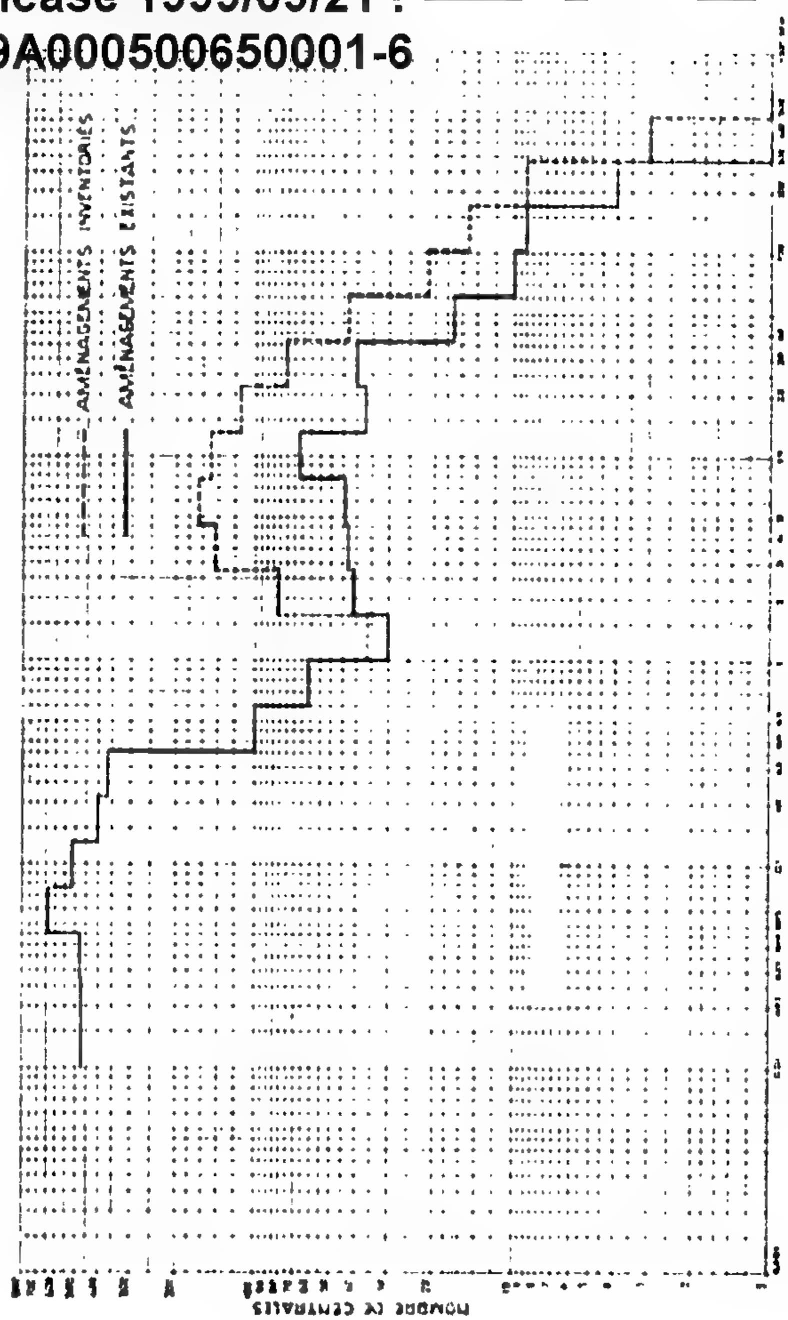

Fig 5 — Polygone de fréquence de la taille des centrales

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... des petits aménagements fréquemment évoqués ... appartiennent néanmoins à un avenir rapproché plus qu'à une urgence immédiate.

Les normalisations concernent également les groupes qui forment un total statistique alléchant de 2 000 unités. Si l'on reporte les puissances unitaires des groupes et les puissances installées des centrales sur un diagramme (Q, H) débit-hauteur de chute, on peut opérer une première concentration de points en jouant sur le fractionnement.

On peut ensuite définir sur les amas les plus significatifs une zone relevant d'un modèle unique de la façon suivante. Le choix des caractéristiques nominales du projet permet une marge de l'ordre de ± 5 %, au moins sur le débit sans perte de bénéfice appréciable sur l'optimum théorique, et une marge pratiquement nulle sur la hauteur de chute, sauf cas d'espèce.

A ceci s'ajoutent, pour les turbines, les marges possibles sur le placement de la colline de rendement qui sont très variables d'un type à l'autre et d'un problème à l'autre; pour les Kaplan par exemple on peut observer des déplacements possibles de 10 à 20 % en surcharge. On définit ainsi sur le diagramme (Q, H) des zones parallélogrammes à l'intérieur desquelles on peut adopter des machines de même tracé.

La question se simplifie pour les alternateurs, où l'on définit alors les marges correspondantes pour une vitesse synchrone donnée en jouant sur le facteur de puissance. Les transformateurs se prêtent à une étude du même ordre.

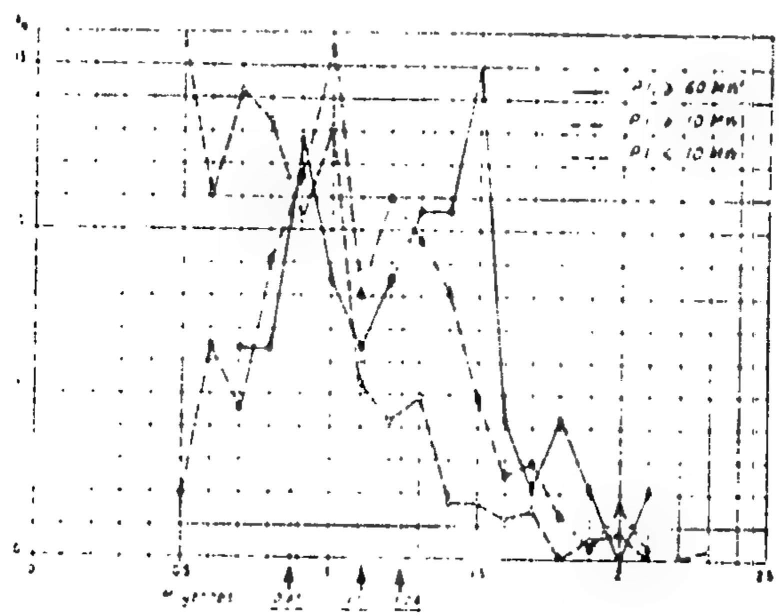


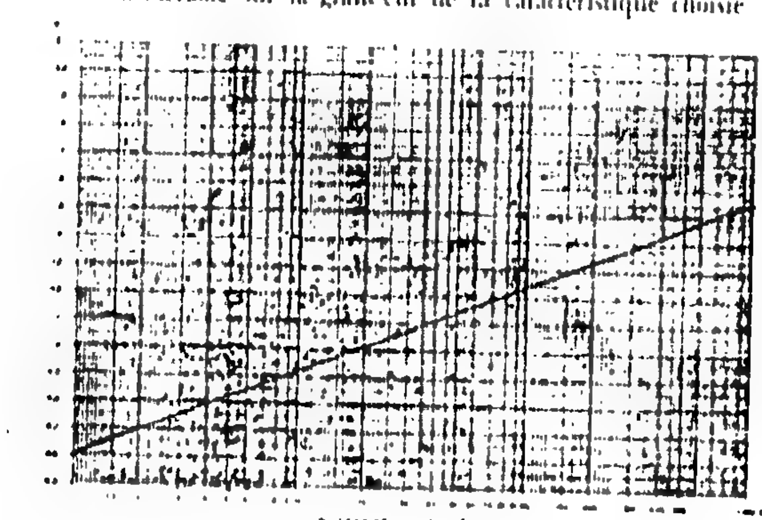
Fig. 6 — Fréquence des centrales en fraction de leur valeur pour trois catégories de taille.

La normalisation partielle ou totale ne paraît pouvoir comporter [illegible] 5 ou 10 Mw, où l'on peut escompter des séries suffisantes ([5]) ou la perte d'un point de rendement a moins d'importance relative. Il est clair qu'il sera toujours payant de rechercher le maximum absolu de rendement sur les grosses unités, tandis que la normalisation des très petites unités du type microcentrale (50 à 100 kW) est une condition économique nécessaire qui peut tolérer des pertes importantes de rendement allant jusqu'à 10%.

C'est là essentiellement un problème de constructeur, sur lequel un developpement ultérieur de petites et moyennes forces hydrauliques (et aussi la mise en commun de statistiques internationales élargissant considérablement les séries), peut forcer l'attention, car l'étude "sur catalogue" de ces catégories de projets paraît être la seule solution viable.

Détermination des Caractéristiques en Calcul Marginal

Si l'usage du critère V est relativement sûr l'ensemble d'un projet et conserve en tout cas une bonne valeur de comparaison, il est beaucoup plus aléatoire sur les opérations marginales qui donnent théoriquement les caractéristiques optimum du projet pour une limite V_m (nous admettons actuellement $V_m = 1$). On constate par exemple qu'une puissance de pointe ou le volume d'un réservoir étant déterminés par la limite marginale V_m, il suffit d'une très petite variation au-dessous de V_m ou encore d'un faible écart relatif sur les prix et les constantes pour obtenir un écart considérable sur la grandeur de la caractéristique choisie.



PUISSANCES INSTALLÉES

Fig. 7 — Corrélation taille — valeur des aménagements. Loi statistique de la Valeur moyenne en fonction de la taille.

([5]) Il semblerait qu'une série d'une dizaine de machines abaisserait le coût unitaire de 20% environ.

[illegible] programme à partir des « décrochements » [illegible] optimum à partir de projets de caractéristiques données, il n'est pas sûr que l'établissement de ces caractéristiques corresponde lui-même à l'optimum pour la composition considérée.

En toute rigueur on serait amené à préparer les programmes non seulement à partir des opérations principales mais aussi à partir de suites innombrables d'opérations marginales, ce qui dépasse évidemment l'imagination.

Une exploration qualitative de l'inventaire permet de pallier dans une certaine mesure les difficultés théoriques, en exprimant dans les caractéristiques présentes ce qui est contenu dans les coûts futurs des diverses "qualités" de l'énergie, autrement dit en évitant des sous-équipements tendanciels pour telle ou telle qualité.

Par exemple nous pourrions disposer actuellement de réserves suffisantes, établis pour V_u marginal = 1, pour élaborer un programme, mais dans nos programmes ultérieurs la "rareté" des réservoirs (plus exactement leur coût plus élevé) pourrait conduire à des solutions plus chères que si nous avions admis un seuil V_u plus bas, ou pris des dispositions prévisionnelles de surélévation des barrages; un cas type est celui de la grande Dixence. Dans un autre exemple, toujours aussi schématique, on pourrait regretter de ne pas avoir ménagé dans un projet favorable à cet égard un groupe complémentaire de pointe de valeur inférieure à l'unité, si la suite des événements devait montrer que cette même puissance de pointe ne peut être établie ailleurs qu'à des conditions plus onéreuses encore.

Moyennant une retouche des seuils de valeurs des opérations marginales, on conserverait ainsi la notion d'équivalence thermique comme étalon de mesure, mais en corrigeant son usage trop absolu pour la détermination de la dimension des projets.

* * *

Ces explorations approfondies dans l'ordre économique sortent sans doute des habitudes courantes mais paraissent hautement payantes en regard des bénéfices à escompter. Nous nous sommes bornés à exprimer certaines perspectives dont il faudra extraire à l'usage les bonnes et les mauvaises. Elles tendent à justifier une poursuite plus approfondie des études d'inventaire, dont l'objectif de départ était plus modeste et se bornait à l'ordre de grandeur des ressources dont on peut raisonnablement escompter l'aménagement.

Résumé

L'inventaire complet des ressources hydroélectriques jusqu'à une très basse limite de valeur relative, au sens actuel du terme, représente une tâche modérée moyennant des méthodes appropriées de prospection et

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d'évaluation. Son intérêt dépasse celui de la connaissance de l'étendue [illegible] dont seule la sommation de projets concrets peut donner une évaluation assez exacte. L'analyse des renseignements économiques et statistiques fournis par l'inventaire ouvre de nombreuses perspectives sur la préparation des programmes, sur l'organisation des études, sur certaines orientations techniques, et d'une façon générale sur tous les problèmes de développement. Bien que l'inventaire n'ait de valeur que moyennant une constante révision, il constitue un matériau de base indispensable aux questions de planification.

Les résultats indiqués sont relatifs au Territoire Français Métropolitain.

Summary

The complete inventory of water power resources, to a very low limit of their relative value, this term being heard in its real signification, is a moderate task, by means of convenient methods for prospection and estimation. Its interest exceeds that of the knowledge of the hydraulic resources extent, of which only the sum of the effective projects may give a rather accurate estimation. The analysis of economical and Statistic informations provided by the inventory, opens a wide prospect in the preparation of the equipment programs, on the organisation of the studies, on some technical trends and generally on the problems of development. Though such an inventory is valuable only if it is constantly reviewed, it represents an indispensable basis in relation with questions of planning.

The indicated results are only for French Metropolitan Territory.

CONFERÊNCIA MUNDIAL DA ENERGIA
WORLD POWER CONFERENCE

Título 2
Assunto 2 1 2

REUNIÃO PARCIAL
SECTIONAL MEETING
Rio de Janeiro — 1954

GULDBERG-MOLLER (V.)
Dinamarca

DIESEL PLANTS IN THE TROPICS

By V. GULDBERG – MOLLER
Mechanical Engineer, M.Sc. (Burmeister & Wain, Copenhagen)

DANISH NATIONAL COMMITTEE

I. INTRODUCTION

Even today there are vast regions in the tropics which are thinly populated. In these regions the population groups itself in small towns far from each other. In thickly populated regions centralization of the electric supply can be arranged to advantage through single big power stations. However, under the above conditions small towns with great distances between each other such centralization will mean long transmission distances and by this increase the cost of the supply mains and great losses in same. Small electric power stations must therefore be employed instead and the ideal prime mover for such words is the diesel engine. In distinction to other prime movers even small units have a high efficiency, and their fuel in form of oil fuel is easy to transport.

Furthermore, experience from the big number of diesel engines, which are installed under tropical conditions, has shown that they do not present difficulties when running under such conditions, on the contrary, this type of prime mover is most excellently suited for service in the tropics.

It appears from the above that when diesel plants are mentioned in this paper it means especially stationary diesel engines, coupled to electric machinery for the purpose of producing electricity machinery for the purpose of producing electricity. But many of the view points stated have just as great importance for diesel engines whether they are installed in ships as main propulsion engines or auxiliary engines, or installed in vehicles for traction purposes.

Below each of the conditions, which, even though they occur outside the tropics, must be considered as typical for the tropics, are dealt with. First of all we naturally think of *high air temperature* and *humidity*. *Erection at great heights* must, even though it can also occur under

[...]ter climates, be considered as special for the tropics, where people often more highly [...] the heat. *Scarcity of water* for the cooling of the diesel engine is a difficulty which must often be overcome. *Insects* are also a drawback and lastly *dust* which is specially expressed in the dry regions of the tropic zone.

II. HIGH AIR TEMPERATURE

a. Diesel engine

Its output is among others dependable on the amount of air drawn or blown into the cylinder. This is partly due to the fact that the less air there is in the cylinder, the less amount of oxygen is available for combustion. Partly it is due to the more oil burnt in a certain amount of air the higher the temperature rises, and thereby the heat stresses in the engine. For one and the same engine the weight amount of air in the cylinder under otherwise unaltered conditions varies with the temperature of the air, as the specific gravity of air is inversely proportional to the absolute temperature at a given unaltered pressure. If the maximum temperature is set, by which the engine yields its normal output, at 85° F (29.4° C), the percentage reductions in the specific gravity of air due to increasing temperature will be seen from the table below, in which the corresponding deductions in the indicated and effective horsepower is also shown; the figures are based on an output of 100 I.H.P.

Temp. in degrees F	Temp. in degrees C	Reduction in spec. grav. of air	Indicated H.P.	Idling loss	Effective H.P.	Deduction in E.H.P.	Deduction acc. to British
85	29.4	0%	100	20	80	0%	6%
95	35	1.8%	98.2	19.8	78.4	2.50%	2%
105	40.6	3.6%	96.4	19.6	76.8	4.00%	4%
115	46.1	5.2%	94.8	19.5	75.3	5.87%	6%

Reduction in capacity for alteration in temperature is set by the British Standard, 649:1949 in the following way:

"For any increase of the ambient (engine room) temperature above 85° F (29.4° C) a deduction shall be made at the rate of 2% per 10° F (5.6°C)". The corresponding deductions are stated in the last column in the above table.

b) The electric equipment

Electric equipment such as alternators, dynamos etc. are dimensioned, among others, according to the insulation material employed, which should have a suitable long lifetime under the temperature imposed

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on same. Therefore the output allowed for a definite machine is de- [illegible]re, that is to say in most cases the air temperature.

Those insulating materials which could be employed are divided into various classes according to their resistance against heat. Thus, class O: Cotton, silk, paper, and similar organic materials when neither impregnated nor immersed in oil; class A: Same materials when impregnated or immersed in oil, also enamel; class B: Mica, asbestos, and similar organic materials in built-up form combined with binding cement. For the tropics class B materials are mostly chosen, and for such materials British Standard 168:1936 with amendment No. 2: November, 1945 states for windings and for cores with which they are in contact a permissible temperature-rise of 50° C (90° F), measured

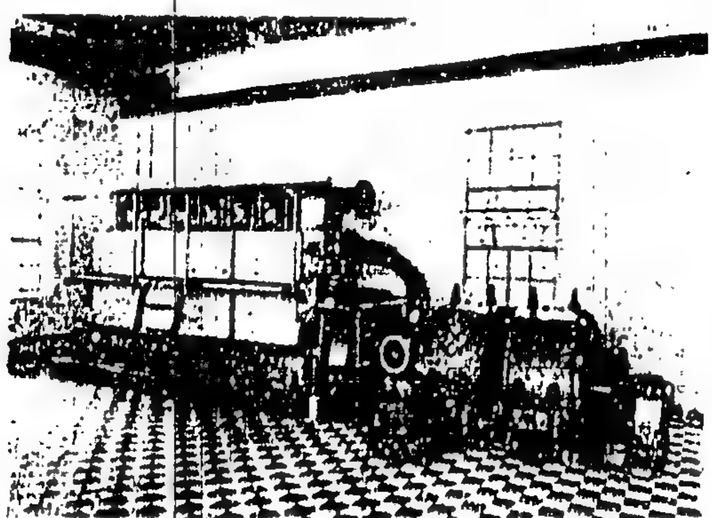


Fig. 1 — Diesel engine 420 B.H.P., 500 r.p.m. (Burmeister & Wain, Copenhagen), coupled to a double dynamo 2 x 140 kW (Thrige, Denmark).

by thermometer, for machines other than totally enclosed. As the maximum temperature of the air, in the same rule, is set at 40° C (104° F) this means that a temperature of 40° + 50° = 90° C (194° F) is allowed. In case the surrounding air temperature is, instead of 40° C, for example 50° C (122° F), either insulating materials with a greater resistance to heat must be employed or the dimensions of the machine must be increased in such a way that instead of a temperature-rise of 50° C (90° F) it will be only 40° C (72° F) whereby the temperature of the insulating material still remains at 90° C (194° F).

Normally the lifetime of insulating material at the temperatures of the standards is 25-30 years. As the speed of deterioration for insulating material is meanwhile an exponential function of the temperature, this

develops [illegible] the temperature: if the temperature is only in- [illegible] the lifetime will be half of that mentioned. It will therefore be noted that only a slight surpassing of higher temperature than predicted, can cause damage. Further to this can be added that the temperature of an electric machine increases to the 2nd power of load in such a way that even a small excess of the load, which corresponds to the permissible maximum temperature, should be avoided in places where the air temperature is close to the maximum foreseen.

American Standard of Rotating Electrical Machinery states as the above mentioned British Standard 40° C (104° F) as maximum ambient temperature. Permissible temperature-rise is somewhat different from the British Standard, as in such a way, e.g. for cores and mechanical parts in contact with or adjacent to insulating in the case of class B insulation and generators having a 2 hour 25% overload rating, a temperature increase of 60° C (108° F), measured by thermometer is permissible.

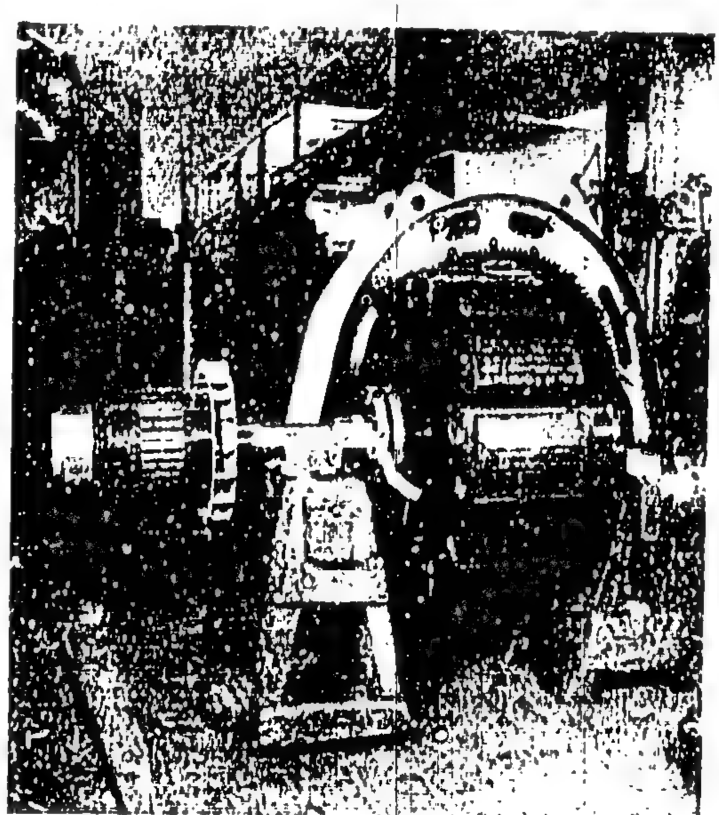


Fig. 2 — Rotor and exciter armature for an alternator (Thrige, Denmark)

III. HUMIDITY

a. Diesel engine

At high temperature and high degree of air humidity the water content of the air will be great and thereby its percentage content of free oxygen reduced. Under such conditions the oxygen available for the combustion may be insufficient to burn the amount of fuel oil which would otherwise be possible under normal conditions. Admitting a vapour pressure of 15 mm before reducing the output and basing the calculations on an atmospheric pressure of 750 mm, the below indicated deductions for humidity will be arrived at:

Vapour press.	Partial air pr.	% of vapour	IHP	Idling loss	EHP	Deduct. %	Deduction acc. Br. St.
15 mm	735 mm	0.0%	100	20	80	0%	0%
35 mm	715 mm	2.7%	97.3	19.7	77.6	3%	3.2%
55 mm	695 mm	5.4%	94.6	19.4	75.2	6%	6.4%
75 mm	675 mm	8.2%	91.8	19.2	72.6	9.2%	9.6%

Deduction in capacity for humidity is set by the British Standard 649:1949 in the following way, the corresponding figures having been inserted in the last column of the above table: "Where combinations of high atmospheric temperature and humidity occur, a percentage deduction from the rated output of the engine shall be made in accordance with the following table, which is based on a deduction at the rate of 4% per inch of mercury (1.6% per cm of mercury) above 0.6 inch (15 mm) vapour pressure".

Atmospheric temp. in °F	Percentage humidity									
	10	20	30	40	50	60	70	80	90	100
85		–			–	0.5	1.0	1.5	2.0	2.4
90	—	–		–	0.4	1.0	1.6	2.2	2.7	3.3
95	—			0.2	0.9	1.6	2.2	2.9	3.6	4.2
100				0.7	1.5	2.2	3.0	3.8	4.6	5.3
105	–	–	0.3	1.2	2.1	3.0	3.9	4.8	5.7	6.6
110	–	—	0.7	1.8	2.8	3.8	4.9	5.9	6.9	8.0
115	–	–	1.2	2.4	3.6	4.8	6.09	7.2	8.4	9.6
115		—	1.2	2.4	3.6	4.8	6.0	7.2	8.4	9.6
120	-	0.4	1.7	3.1	4.5	5.9	7.3	8.6	10.0	11.4
125	—	0.8	2.3	3.9	5.5	7.1	8.7	10.2	11.8	13.4

The diesel engine manufacturer must also consider other aspects of the humidity when supplying to the tropics, as it, in conjunction with heat, causes the rapid formation of rust and corrosion. It is therefore necessary to take special precautions when packing engines for the tropics. Painting and greasing must be carried out with special care; the

fuel oil system should be emptied, as the fuel oil may attack the polished surfaces of the pumps and valves; after tapping the fuel oil the system should be filled with clean parafin oil free of acids. Before the engine is dismantled on the test bed the normal lubricating oil can be drawn off and the engine run with a special oil which leaves a protective layer on all parts in touch with it. Lastly all special sensitive parts should be covered with plastic ("Cocooning").

b. The electrical machinery

Humidity in the air does not mean any reduction in the output of the electrical machinery, but in other ways precaution must be taken against it.

Even though the electrical machinery is dried out in ovens at the manufacturers works and thereafter varnished it is always necessary to dry same out again after despatch and erection on site. This drying out, for example an A.C. generator, is usually done along the following lines: After shorting the armature the generator is run at normal speed and magnatized so that the current in the stator is 25-30% higher than at normal load. For low tension machinery an insulating resistance of 0.5 megohms is sufficient, while for high tension machinery 5-10 megohms are demanded. In humid climates a dry-out must be made every time a machine has stood idle unless, by incorporatingi heating elements in the machine, e.g. 3 elements fitted to the lower part of the frame at intervals, will keep same dry. By this method it is possible to put the machine in service without preparation. For large size gerators, each element can be up to 2 kW; for generators of 200-400 kW, e.g. 3 x 500 Watt.

When selecting insulating material regard should be taken to humidity, the insulating material should be as non-hygroscopic as possible. The cotton tape, which is used for windings in dry regions, should be replaced by oil cloth for use in tropical regions.

IV. ALTITUDE

a. Diesel engine

Under otherwise even conditions the specific weigth of air varies in proportion to the barometric pressure and thereby in proportion to the altitude. Through this the output will vary by height as the amount of air in the cylinder decreases.

How the air pressure varies through height depends on the temperature variation. Assuming a temperature drop of 5° C per 1 000 metres, a distribution of air pressure in various heights will be reached as shown in the table below , adopting the normal temperature of 85° F (29.4° C) of the British Standard 649:1939 at each single altitude:

Height	Air		Idling loss	CHP	Output %	Reduction in output %	British Standard %
0	100	100	21.0	80	100	0	0
1 000	89	89	18.0	70.1	87.5	12.5	11.1
2 000	80	80	17.9	62.1	77.6	22	21.2
3 000	72	72	17.0	55.0	68.6	31	37.4
4 000	65	65	16.1	48.9	61.2	39	50.5
5 000	58.5	58.5	15.3	43.2	54.0	46	63.6
6 000	52	52	14.5	37.5	46.6	53	76.8

With reference to deduction in output for erection on heights the British Standard 649:1939 states the following: "For decrease in the atmospheric pressure a deduction from the rated output of the engine shall be made at the rate of 4% per inch of mercury (1.6 per cent cm of mercury, or at the rate of 4% per 1 000 feet (305 metres) of altitudes above 500 feet (152.5 metres), whichever is lesser". The corresponding figures to this rule are given in the last column of the above table.

b. The electrical machinery

As the cooling ability of the air decreases as to the specific weight, i.e. as to the pressure, the electrical machinery to be erected on heights

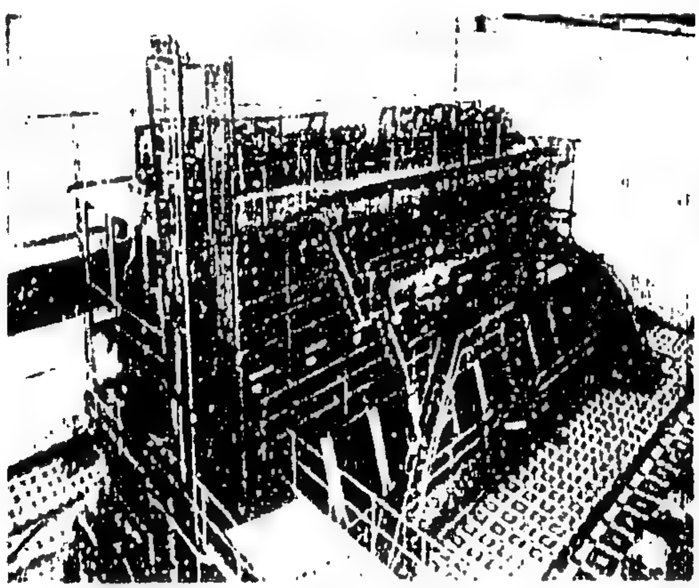


Fig. 3 — Diesel engine, 22,500 B.H.P., 115 r.p.m. (Burmeister & Wain, Copenhagen), coupled to an alternator 15,200 kW (ASEA, Sweden).

Hütte, 1941, Volume I, page 411, table 2

must be more amply dimensioned than those to be erected on low sites, assuming even temperatures. In this respect British Standard 168:1936 states the following: "When a machine intended for service at altitudes between 3,300 feet and 10,000 feet is tested near sea-level, the limits of temperature rise shall be reduced at the rate of 1½% for each 1 000 feet above sea-level at which the machine is intended to work in service. The correction shall not be applied for altitudes below 3.300 feet".

American Standard of Rotating Electrical Machinery, March 29, 1943, have a corresponding rule reading as follows: "For machines designed not to exceed the standard temperature rise at altitudes from 3,300 feet (1 000 metres) to 13,000 feet (4 000 metres) the temperature rises as checked by test at low altitude shall be less than specified in these standards by 1% of the specified temperature rise for each 330 feet (100 metres) of altitude in excess of 3 300 feet (1 000 metres)".

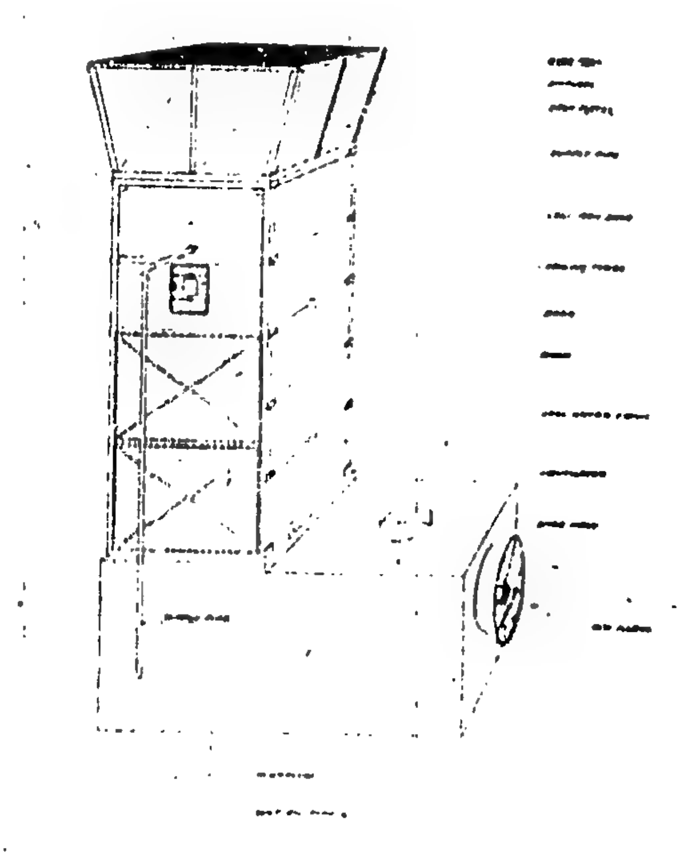


Fig. 4. — Cooling tower with forced draft (Glent & Co., Copenhagen)

V. COMBINATION OF REDUCTIONS

Having a given aggregate and knowing the permissible output of [illegible] machine under normal conditions (for example under British Standard) and which is to be erected on a site with a higher temperature and greater altitude than normal, it is possible from the above, to calculate how much the deduction in output will be so that the aggregate is not overloaded; naturally the greatest deduction arrived at, whether it applies to the diesel engine or the electric machine, must be employed. The necessary deduction, according to British Standard, is reproduced graphically, partly for temperature, and partly for height.

It will be noted from the first graph that below 114° F (45.5° C) the deduction in the output of the diesel engine is decisive and above this temperature that of the electrical machinery. The mentioned temperature — fortunately — rarely presents itself and it is thus, in most cases, the deduction of the diesel engine output which is to be applied. From the second graph it will be noted that in case of deduction for altitude it will always be that of the diesel engine which is decisive.

In most cases where a plant is to be erected in the height, the temperature will not be particularly high, while most places with high tempe-

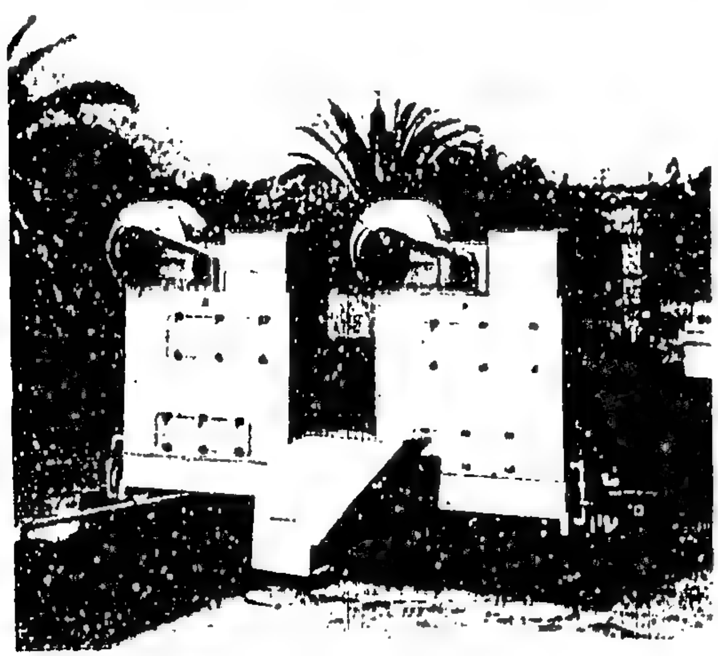
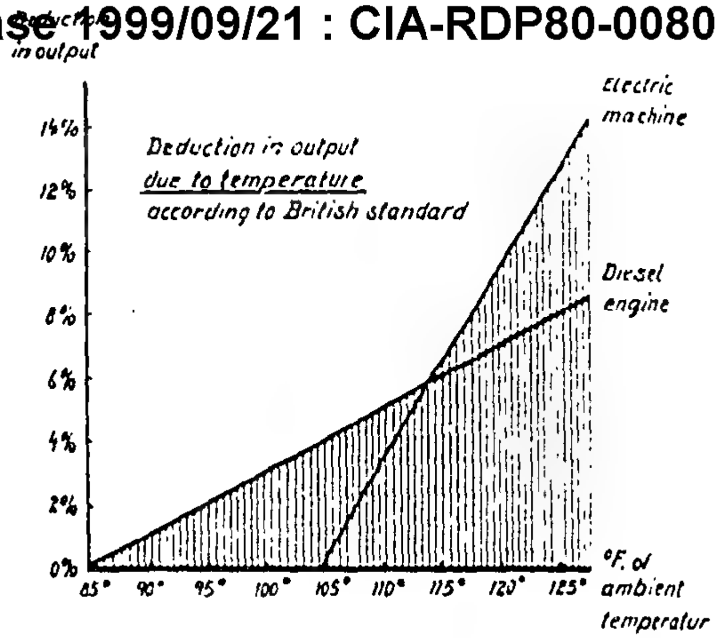
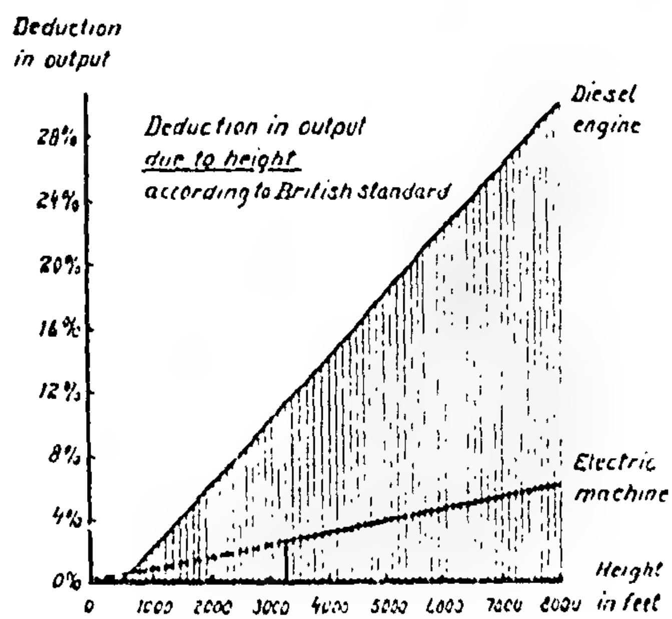


Fig. 5 — Cooling towers installed outdoors (Recold "Dry Fan" type, Atlas Ltd., Copenhagen


Deduction in output
Electric machine
14%
12%
10%
8%
6%
4%
2%
0%
Deduction in output due to temperature according to British standard
Diesel engine
85° 90° 95° 100° 105° 110° 115° 120° 125°
°F. of ambient temperatur


Deduction in output
Diesel engine
28%
24%
20%
16%
12%
8%
4%
0%
Deduction in output due to height according to British standard
Electric machine
0 1000 2000 3000 4000 5000 6000 7000 8000
Height in feet

[illegible] at low altitudes. In cases of great altitudes and high temperatures, the two deduction must be bultiplied. If the [illegible] for temperature the total deduction will be: 0.97 x 0.96 = 0.931, i.e. about 6.9%. The same applies for deduction in conjunction with humidity, if this presents itself at the same time.

VI. COMPENSATION THROUGH TURBO-CHARGE

The above mentioned deductions of output apply for naturally aspirated diesel engines and also for turbo-charged diesel engines whose super-charge blowers are based on normal atmospheric conditions.

Meanwhile deduction in output of supercharged engines can be avoided on condition that, before delivery, details of the atmospheric conditions on site are received. As the deduction is always caused by reduction in the amount of air in the cylinder, this can be compensated by employing a supercharge blower with a higher compression ratio

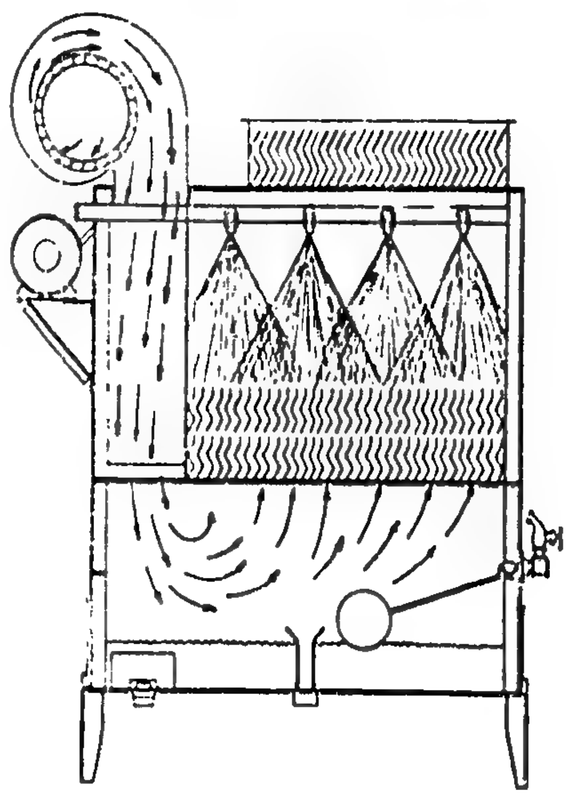


Fig. 6 - Section through cooling tower of the cabinet type (Recold "Dri-Fan" type), Atlas Ltd., Copenhagen

than would be ... normal atmospheric conditions, possibly in connection with an intermediate cooler to cool the super charge air ... available.

VII. COOLING WATER

For a diesel plant cooling water of a temperature of maximum 40 — 45° C (104 — 113° F) is required. This is due to the fact that the lubricating oil must be cooled as much as possible, at least down to 50 — 55° C (122 — 131° F). For the diesel engine itself the temperature of the cooling water should be so as to give the correct temperature of the cylinder surface, viz. above the dew-point of the combustion gases and below the temperature at which the oil film on the cylinder wall is destroyed. Experience shows that such conditions are approximately obtained when the inlet temperature of the water to the engine itself is from 45° C (113° F) up to 70° C (158° F, the lowest figure corresponding to the biggest engine types and the highest to the small engines.

Where plenty of good quality water, i.e. without impurities, is available in a lake or river, such water can be used directly as cooling water, being taken through the lubricating oil cooler and the diesel engine, possibly so that the cooling water, after passing through the lubricating oil cooler, is mixed with the outlet cooling water from the engine to increase, if necessary, the temperature before the inlet to the engine.

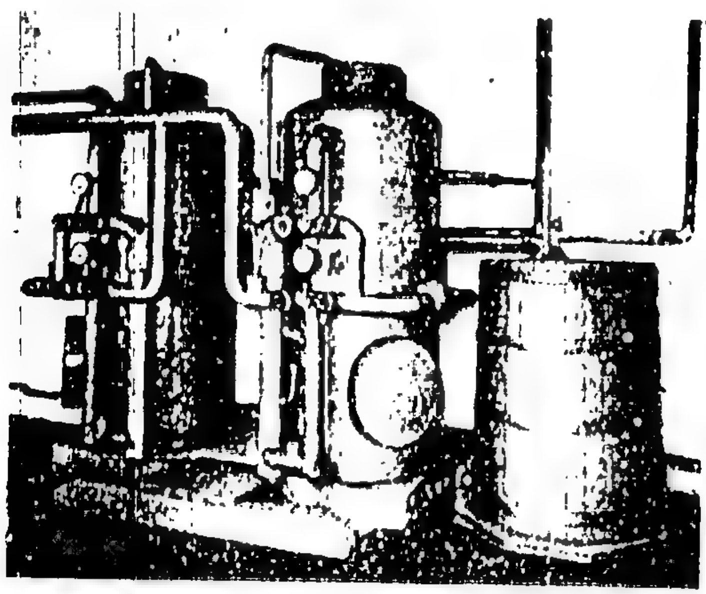


Fig. 7 — Ion-exchange filter, producing salt inactive water according to invention of C. H. V. Page (Giert & Co., Copenhagen)

[illegible] clean cooling water is scarce. Water may be plentiful but then it is usually the question of salt water [illegible] the cooling should be from the arranged through an indirect cooling system, as by employing the water itself as cooling medium in the engine itself it would not be possible to have a higher outlet temperature of the salt water than 45° C (113° F), due to the salt incrustations forming in the cooling spaces of the engine at higher temperatures. The correct way is to lead the sea water through the lubricating oil cooler and from there to a heat-exchanger for cooling the clean fresh-water which by an additional pump is circulated through the cooling spaces of the engine. This principle may also be used in cases where the engine is installed near a river, the water of which will often be too dirty to pass through the engine.

Where there is a shortage of water the employment of a cooling tower may be necessary. This can be formed in many ways but the

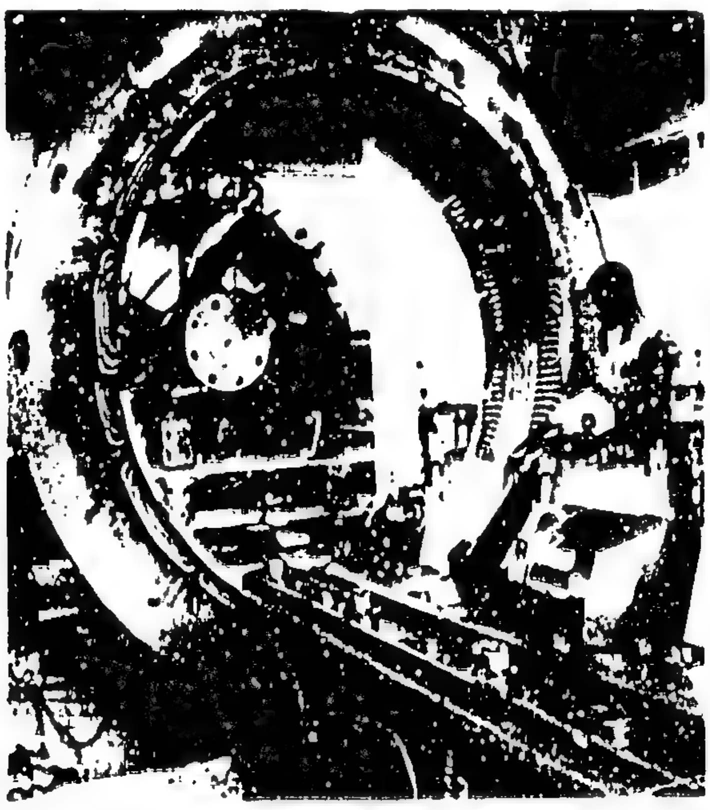


Fig. — Erection of an alternator. The winding and their insulation are clearly seen. (Thrige, Denmark)

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[illegible] surface and thereby facilitate the [illegible] cooling tower is often made by erecting [illegible] ing on top of this a square wooden tower with a [illegible] boards fixed at acute angles to obtain the [illegible]. The outlet pipe from the diesel engine goes [illegible] the top of the tower following all four walls, the end of the pipe [illegible] a number of sprinklers are fitted through which the water is sprayed over the top boards and runs along the surfaces of the [illegible] back into the tank. The efficiency of this arrangement can be increased by fitting a fan to blow air through the tower.

For big diesel engines the cooling tower should be delivered by firms specializing in such, thereby ensuring that the capacity of the

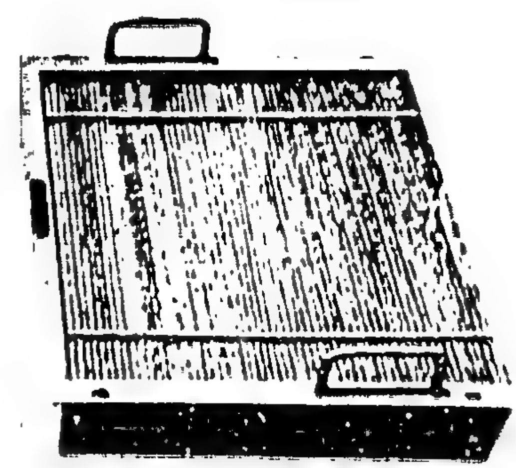

Fig. 3. Air filter cell, Viscous type. Made in Czechoslovakia [illegible]

tower is suitable under the climatic conditions on the site. A manufactured cooling tower is normally made of section iron and galvanized iron sheets, and in many cases enclosed by an attractive cabinet.

With a view to having the cooling water for the lubricating oil cooler at a lower temperature than that of the diesel engine itself, the cooling water system can also in case of a cooling tower be arranged [illegible] mentioned above, viz. by making the cooled off water from the cooling tower pass through the lubricating oil cooler and thereafter [illegible] by-pass water from the diesel engine before it is fed into same [illegible] is obtained cold water for the lubricating [illegible] water [illegible] engine.

[illegible] evaporation amounts to about [illegible] liter per E.H.P. [illegible] evaporation the concentration [illegible] the remaining water [illegible] minerals steadily increases [illegible] it is therefore necessary to drain [illegible] circuit and by adding fresh water [illegible] make up for both the evaporated and for the drained off water. Further it cannot be avoided that [illegible] of the fine water particles are blown away thereby causing a further [illegible] of water. A consumption of water of about [illegible] liter per E.H.P. [illegible]

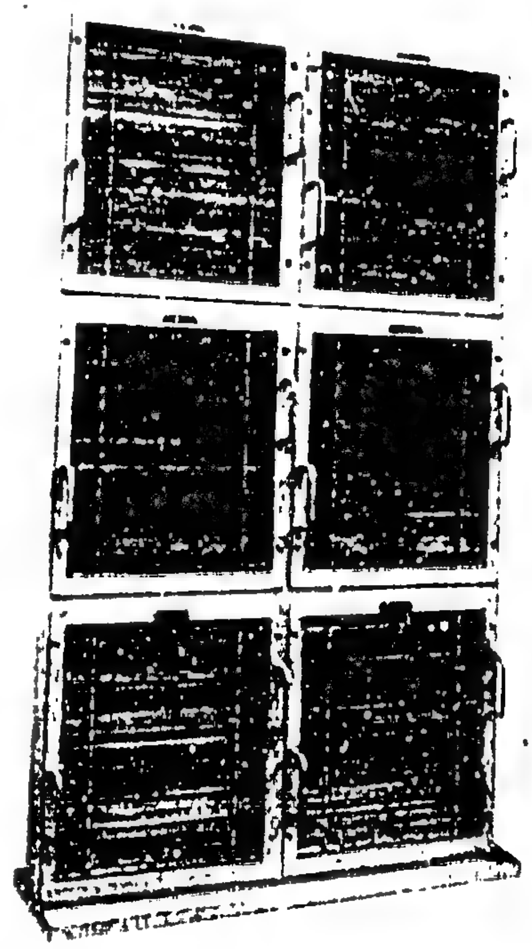

Fig. 10 — Air filter assembly for building into a wall. Ventilat type. Mat[illegible], C[illegible]

[illegible]

It [illegible] the [illegible] tower.

In cases where there [illegible] must be applied [illegible] the [illegible] a great surface being cooled by an air flow from a ventilator [illegible] which everyone knows from the motor car. For [illegible] plant [illegible] system may consist of two parts, one for the engine cooling water and one for the lubricating oil. While through the application of a cooling tower, it is possible to get the water temperature close down to air temperature especially in cases of relatively dry air, this is not possible the [illegible] radiator cooling. Also the running cost of a radiator cooler [illegible] to the rather high power needed to drive the fan.

VIII INSECTS

Insects were also mentioned in the introduction as a [illegible] the tropics. For the diesel engine itself there is [illegible] of some trouble to the electrical machinery. The insulating material should be selected with this point in mind. For electrical machinery in the tropics class B material is mostly chosen. As for winding [illegible] the slots of the armature mica insulation is [illegible] to insect attack. The winding heads may for instance be wound with three layers of [illegible] cloth covered with five coatings of enamel paint which is so hard that it makes insect attack practically impossible. Terminal boxes are normally made of Novont, but for the tropics they should be of the porcelain type. It is particularly ants and termites that attack the insulating material, but in Brazil for example, you will find other small insects in the flour mills which work themselves into the insulation making inspection and overhaul of the electric machines necessary every other year.

IX DUST

Within the tropic zone, vast regions exist where the climate is warm, dry and windy and therefore the air full of dust. This dust can cause a great deal of trouble to the performance of diesel generators. As far as the engine is concerned, it aspirates dust together with the combustion air and due to this the wear on the cylinder liners, piston rings, pistons and valves is increased. At the same time the dust may get into the lubricating oil increasing wear in the bearings and other

[illegible] later [illegible] steam [illegible] the danger of the piston rings sticking in the grooves and the engine fouled by the combustion products. If the dust also fouls the fuel oil this must be carefully filtered to prevent wear of the fuel pumps and fuel valves. As for diesel engines with supercharge blowers, the dust can form a layer on the fixed guide vanes of the centrifugal blower, the capacity of which is thereby reduced.

With reference to the electrical machinery, the dust sets in the ventilating channels and thereby hinders the cooling of the machine. Wear on the commutator, brushes and bearings is increased.

To fight these problems air filters must be employed. The working principle of most of the filter types is to split up the air flow, allowing the direction of the smaller flows to be broken several times whereby the dust particles are cast against oily surfaces to which they stick. Usually the filters are built-up in a number of square cells fitted in a common frame to make up a large surface. Each cell can either be fitted with a large number of small and short cylinders, the so-called "Seiler" rings, or with many parallel, wave formed plates. Cleaning of such a filter can be done during running by treating the cells one by one, replacing the cell being cleaned by a spare one. The cleaning is made by washing the cell in a warm soda solution, and when dry it is dipped in oil and left to drip for 12 hours. An individual filter can be arranged for each machine needing air, but usually it is more rational to build a dust-proof engine room with a common filter in one of the walls.

As it will appear from the above there are various points to be considered when employing diesel plants in the tropics. However, as it likewise appears, those problems brought about by tropical conditions are not so great, nor are they difficult to overcome and, in accordance with this, experience has proved them to be, as already mentioned in the introduction, an economical and reliable source of power in the tropics.

Summary

Experience with the many diesel generator-groups installed in the tropics has proved that such groups are excellently suited to work under tropical conditions. In the paper is dealt with the various tropical conditions which require special consideration during construction and in service.

At high ambient temperatures the rating of the diesel engine as well as of the electric machine coupled to it, must be reduced in proportion to the normal rating, namely for the diesel engine about 2% for each 10° F above 85° F, and about 6% for each 10° F above 103° F as far as the electric machine is concerned.

[illegible] weather with effect on humidity [illegible] about 4% deduction per each of [illegible] above [illegible] humidity [illegible]. The humidity of the air must also be considered when packing before shipment and also particularly with reference to the electric machine before being put into service on the site

For service in altitudes de-rating is also necessary for the engine and the electric machine, namely about 4% per 1,000 feet over [illegible] feet and about 3.4% per 1,000 feet over [illegible] feet respectively. If, during manufacture of the diesel engine the prevailing conditions are known at the site where it will be installed, and the engine is of a turbo-charged type, compensation against such conditions can be made by selecting a turbo-charger with a pressure ratio higher than normal

The higher temperature and the often insufficient supply of water in the tropics also present special conditions as far as cooling of the engine is concerned. In many cases a cooling tower must be employed with or without artificial ventilation. Such towers can be made locally and of a primitive construction but can also be had from firms specialising in such work. For locations with a short supply of water the radiator cooling system is employed. This does not however give as efficient a cooling as the cooling tower and the running cost is higher

While the diesel engine is not troubled by insects the electric machine is, and therefore care should be given to this point when selecting insulating materials

In dry and warm regions dust can often be a problem which, as far as the diesel engine is concerned, results in greater wear and reduced efficiency, and for the electric machine it means a less efficient cooling. To avoid these troubles filters are employed, usually of the type built up from cells, which can be cleaned one by one during running. The cells have either 'Seger' rings or parallel wave-formed plates moistened by oil and to be surface of which the dust sticks. Such filters are most practically built into a wall of the engine room

Résumé

L'expérience acquise sur le grand nombre de groupes électrogenes Diesel installés dans les tropiques, a démontré que de tels groupes se prêtent bien à fonctionner sous les conditions tropicales. Le mémoire enumère les différentes conditions tropicales, auxquelles il faut porter une attention particulière pendant la construction et l'exploitation des groupes.

En cas de température ambiante elevée, la puissance du moteur Diesel, aussi bien que celle de la génératrice électrique y attelée, doivent être reduites par rapport à la puissance normale, savoir: pour le moteur Diesel deux pourcent environ toutes les fois que la température dépasserait de 10°F celle de 85°F, et six pourcent environ toutes les fois que la

[illegible]

[illegible] Diesel et la température [illegible] élevée [illegible] quantité d'humidité [illegible] une réduction à raison de quatre pourcent par pouce de mercure de dépression d'un pouce de pression de vapeur. Il y a lieu de tenir compte de l'humidité de l'air pour faire l'emballage avant l'embarquement et tout spécialement en ce qui concerne la machine électrique avant de la mettre en service sur place.

Pour la marche aux endroits élevés, la réduction de puissance est également nécessaire pour le moteur et pour la machine électrique, savoir quatre pourcent les 1.000 pieds à partir de 500 pieds et 3-4 pourcent environ les 1.000 pieds à partir de 3.300 pieds, respectivement. Si, pendant la fabrication du moteur Diesel, on connait les conditions sous lesquelles le moteur doit fonctionner et que le moteur soit pourvue de suralimentation par turbosoufflantes, on peut obvier aux phénomènes ci-dessus par l'installation d'une turbosoufflante ayant une proportion de pression plus élevée que d'ordinaire.

La température élevée et dans beaucoup de cas la rareté d'eau sous les tropiques créent également des conditions spéciales en ce qui concerne le refroidissement du moteur. Dans nombre de cas il faut prévoir une tour de refroidissement avec ou sans ventilation artificielle. De telles tours peuvent être fabriquées sur place et être d'une construction simplifiée. Elles peuvent également être fournies par des maisons spécialistes dans ce domaine. En cas d'une très forte pénurie d'eau, on se sert du refroidissement par radiateurs. Ce dernier procédé n'assure pas une réfrigération aussi efficace que celle assurée par la tour refroidissement et les frais d'exploitation sont plus élevés.

Tandis que le moteur Diesel repousse les attaques d'insectes, il n'en est pas de même de la machine électrique. Pour cette raison, il y a lieu de tenir compte de ce fait au moment de choisir les matériaux d'isolement.

Aux régions sèches et chaudes les poussières constituent souvent un problème ayant pour résultat, en ce qui concerne le moteur Diesel, une augmentation de l'usure et une réduction de l'effectivité. Quant à la machine électrique, son refroidissement serait moins efficace. Pour y remédier on utilise des filtres, le plus généralement ceux composés de cellules susceptibles d'être nettoyées une à la fois, pendant la marche. Les cellules sont munies d'anneaux "Seqer" ou de tôles ondulées, parallèles enduites d'huile pour retenir les poussières. Le plus pratique, c'est d'encastrer de tels filtres dans l'une des murs de la salle des machines.

RESUMO

Experiência com os vários grupos de geradores Diesel, instalados nos trópicos, tem provado que tais grupos trabalham excelentemente sob condições tropicais. A monografia em questão dá conhecimento das vá-

nas condições tropicais que requerem especial consideração durante a [illegible]

Em ambiente de temperatura elevada a voltagem do motor Diesel tanto quanto a máquina eletrica com ele acoplada, deve ser reduzida em proporção a voltagem normal, particularmente para o motor cêrca de 2% para cada 10° F acima de 85° F, e cêrca de 6% para cada 10° F acima de 103° F no que diz respeito à maquina eletrica.

Baixa adicional de voltagem e necessaria para o motor Diesel se o proprio ar atmosferico de temperatura elevada tambem apresenta grande humidade particularmente: cêrca de 4% de redução por polegada de mercúrio acima de 0.6 polegada de pressão de vapor. A humidade do ar atmosférico deve ser tambem considerada na embalagem antes do embarque, e também, especialmente com referência a maquina eletrica antes desta ser posta em serviço no lugar.

Para serviço em altitude, baixa de voltagem e tambem necessária para o motor e para a maquina eletrica, particularmente, cêrca de 4% por 1 000 pes acima de 500 pes e cêrca de 3.4% por 1 000 pes acima de 3.300 pes respectivamente. Se, durante a fabricação do motor Diesel as condições predominantes, são conhecidas no lugar onde êle vai ser instalado, e o motor é do tipo turbo-carga, uma compensação de tais condições pode ser efetivada pela encolha dum tubo-cargo com uma relação de pressão mais alta do que a normal.

A temperatura mais elevada e a bem frequente insuficiência de suprimento de água nos trópicos também apresenta condições especiais no que diz respeito ao resfriamento do motor. Em vários casos uma tôrre de refrigeração deve ser empregada, com ou sem ventilação artificial. Tais tôrres podem ser feitas no local e de construção primitiva, mas também podem ser obtidas de firmas comerciais especializadas em tal trabalho. Para lugares com pequeno suprimento de agua, o sistema de radiador de refrigeração é empregado. Êste, todavia, não da uma tão eficiente refrigeração quanto a da tôrre de refrigeração e o custo corrente e mais alto.

O motor Diesel não e transtornado pelos insectos, enquanto que a máquina elétrica e. Em consequência disto se deve tomar cuidado, quanto a êsse ponto, na ocasião da escôlha de materiais isolados.

Nas regiões quentes e sêcas a poeira pode ser, frequentemente um problema, o qual, tanto quanto diz respeito ao motor Diesel, resulta num maior gasto e redução de eficiência, e para a máquina elétrica significa uma refrigeraçao menos eficiente. Para evitar êsses transtornos se empregam filtros, usualmente do tipo de celulas, as quais podem ser limpas, uma por uma durante o funcionamento. As celulas têm aneis "Seger" ou chapas paralelas em forma de onda umedecidas por óleo e nas superficies das quais a poeira adere. Tais filtros são praticamente construidos no interior duma parede da sala de maquinas.

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HARNECKER R.
SALAZAR R.
SANTA MARIA D.
Chile

PRINCIPIOS TÉCNICOS Y ECONÓMICOS DEL APROVECHAMIENTO INTERNACIONAL DE LAS AGUAS DEL LAGO TITICACA

Por el Prof. Ing. REINALDO HARNECKER,
Prof. Ing. RENATO SALAZAR
y Ing. DOMINGO SANTA MARIA

COMITE NACIONAL CHILENO

El desarrollo futuro de Bolivia, Chile y Perú y el bienestar de sus pueblos depende de la capacidad que estos países tengan para elevar considerablemente su producción agrícola e industrial. Esto significa poder disponer de energía y de materias primas. Es probable que este [illegible] lo reúnan [illegible] los tres países en común. Para desarrollarlo sería conveniente iniciar cuanto antes el estudio del uso racional de las aguas del lago Titicaca y la posible formación de una zona industrial y agrícola en el litoral chileno-peruano del océano Pacífico y en el altiplano boliviano donde parecen existir favorables condiciones para ello.

INTRODUCCIÓN

En la 4.ª Conferencia Mundial de la Energía, realizada en Londres en 1950, el Comité Nacional Chileno presentó un trabajo sobre los recursos hidroeléctricos utilizables para la industria electroquímica y electrometalúrgica en gran escala(*), entre los cuales se incluía el aprovechamiento de las aguas del lago Titicaca.

Desde esa fecha, los círculos de ingenieros de Bolivia, Chile y Perú se han mantenido activos con respecto a destacar la posibilidad de realización y la importancia de este gran proyecto. Es así como en la 7.ª

(*) Trabajo [illegible] de la Sección H-1 preparado por el profesor ingeniero señor Reinaldo Harnecker, uno de los autores del presente trabajo.

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Convención de la Unión Sud Americana de Ingenieros (USAI), celebrada [illegible] una resolución que recomienda a los Gobiernos de los países interesados, Bolivia, Chile y Perú, proceder a efectuar el estudio conjunto del aprovechamiento hidroeléctrico de las aguas del Lago Titicaca.

El presente trabajo está destinado a mostrar los inconvenientes de algunas de las soluciones y las ventajas de otras para el desarrollo hidroeléctrico que aproveche las aguas del mencionado Lago, en consideración a principios técnicos y económicos y a insistir en la necesidad de iniciar cuanto antes los estudios completos, en vista de la magnitud de las obras y del plazo necesario para realizarlos.

I CONSIDERACIONES GENERALES

En los estudios de aprovechamiento de los recursos hidroeléctricos se presentan a menudo alternativas, que contemplan un mayor o menor grado de utilización de las aguas en otros fines que la generación de energía, como ser riego de zonas áridas, acondicionamiento de vías fluviales, etc.

La elección de la solución técnicamente más conveniente para el aprovechamiento de las aguas debe ser, sin duda, la que sea económicamente más favorable, entendiéndose por tal aquella que proporcione los mayores beneficios para la colectividad, al avaluarse todos los servicios que deriven en comparación con otras soluciones posibles.

Tanto en los países sudamericanos como en otras zonas industrialmente poco desarrolladas del Mundo, una de las mayores limitaciones en la elección de la mejor solución, desde el punto de vista económico, es la falta de disponibilidad de capital, cuando para alcanzar esa solución se necesita una mayor inversión que la necesaria para otras menos económicas. Esta situación desfavorable puede traducirse en desarrollos hidroeléctricos limitados, que inutilicen posibles desarrollos futuros, privando a vastas regiones en años venideros, ya sea definitiva o temporalmente, de las fuentes más económicas de abastecimiento de energía.

Otra tendencia a elegir una solución restringida puede producirse cuando parte de los beneficios queden fuera de las fronteras nacionales. Esta limitación proviene generalmente de razones políticas y no de razones técnicas, ni económicas.

Es razonable pensar que el desarrollo en forma integral de las grandes concentraciones hidroeléctricas permite obtener costos inferiores de la potencia instalada y de la energía producida, con respecto a los desarrollos parciales. Por otra parte, la disminución del costo de la energía permite ampliar su utilización, en atención a que hace posible el empleo de la electricidad en usos que no se justificarían a costos más altos, como ser en la industria electroquímica y metalúrgica. El agua es un elemento indispensable para el desarrollo de centros agrícolas e industriales y por

ente, su disponibilidad evidentemente contribuye a incrementar el con- [illegible] abundancia de minerales, combustibles y otras materias primas son factores de gran importancia al fin indicado. Finalmente, los medios de transporte adecuados, especialmente los transportes marítimos, complementan el conjunto de condiciones para la formación de núcleos industriales, que hacen posible el consumo de grandes bloques de energía eléctrica.

De las consideraciones anteriores pueden deducirse las siguientes directivas:

1.ª – Para el aprovechamiento de las aguas deberá propenderse a la utilización integral de sus posibilidades, en forma que conduzca a obtener los mayores beneficios a los menores costos unitarios, con desarrollo paulatino si fuera necesario. En consecuencia, deben evitarse las soluciones parciales que inutilicen o perjudiquen a futuros aprovechamientos.

2.ª – En el desarrollo de recursos hidráulicos, el uso combinado de las aguas en diversos fines, como ser en el riego de zonas áridas y en las necesidades industriales, puede complementar la economía general de la solución hidroeléctrica en forma decisiva y contribuir, además, al incremento de la producción de alimentos para atender a la demanda que produzca la industrialización.

3.ª – La ejecución de las grandes obras de utilización integral de los recursos hidráulicos en gran escala puede hacerse más viable si ella sobrepasa las fronteras de un país, cuando esta utilización beneficia a varios.

2. – UTILIZACIÓN DE LAS AGUAS DEL LAGO TITICACA

El aprovechamiento de las aguas del lago Titicaca, situado en el límite entre Bolivia y Perú, a 3.800 m sobre el nivel del mar, constituye un caso característico en que la aplicación de las directivas anteriormente expuestas conducirá a dar solución favorable a las necesidades sociales y económicas de las poblaciones del área continental vecina, que comprende territorios de Bolivia, Chile y Perú.

El lago Titicaca tiene una superficie de 8.800 Km² y las aguas afluentes se evaporan en su mayor parte. El resto escurre por el río Desaguadero, de 350 Km de longitud, que termina en el lago Poopó. Este rebalsa esporádicamente a los salares de Coipasa y de Uyuni, situados en territorio boliviano. Este sistema hidrográfico no tiene aprovechamiento substancial. La utilización de estas aguas implica desviarlas hacia el Atlántico o hacia el Pacífico, ya sea cruzando el cordón oriental o las mesetas altas occidentales de la Cordillera de Los Andes, a fin de obtener alturas de caída y terrenos áridos que regar.

Para el aprovechamiento de las aguas del lago Titicaca, entre las soluciones estudiadas hasta el presente, existen, en primer término, las que consultan desviarlas hacia el Atlántico. Se ha pensado hacerlo, extrayendo

del lago un caudal limitado, de unos 20 m³ seg., al valle del río San [illegible] y del Amazonas, con aprovechamiento de una porción limitada entre 1.670 y 1.820 m. de la altura de caída disponible. A estas soluciones corresponden los estudios que hasta ahora se encuentran más avanzados. Están concebidos para la instalación de una potencia moderada, del orden de 300 MW, estimada suficiente para el abastecimiento de las necesidades presentes y de un limitado consumo futuro de Bolivia y zonas vecinas de Chile y Perú.

Las soluciones mencionadas, de desviación de las aguas hacia el Atlántico, podrán ampliarse al perseguir su aprovechamiento máximo para la generación de energía. En primer lugar, el caudal de 20 m³ seg., estimado como caudal máximo que podría extraerse para mantener el nivel medio actual del lago, podría ser aumentado considerablemente.

Según estudios preliminares, basados en los datos metereológicos e hidrológicos actualmente disponibles y en apreciaciones de la topografía del lago, se obtendría una apreciable disminución de la evaporación por medio del descenso del nivel medio del lago, en 7 a 8 m. El caudal regulado que podría ser extraído del lago en forma permanente, alcanzaría probablemente así a unos 80 m³ seg. Además, el desnivel aprovechable podría ser aumentado con caídas mayores que las contempladas en los estudios hechos. Una apreciación somera del desnivel económicamente aprovechable en los valles que se extienden hacia el río Beni, permite fijar la altura total aprovechable en 3.000 m. Al tomar en cuenta las pérdidas de caída en las aducciones y los rendimientos de las máquinas motrices, la potencia media total aprovechable, mediante la desviación de las aguas hacia el Atlántico, con extracción de 80 m³ seg., puede estimarse en 1.900 MW. En atención a la regulación que proporciona el lago, el caudal sería permanente y permitiría obtener energía base ascendente a unos 17.000 millones de KWH anuales.

Las principales observaciones que fluyen de inmediato de la desviación de las aguas hacia el Atlántico, son:

1.ª — El agua del lago Titicaca desviada hacia el Atlántico no tendría otro aprovechamiento que en la generación de energía eléctrica.

2.ª — La potencia final disponible de 1.900 MW, dada su ubicación, sería desproporcionada a las posibilidades de consumo de las zonas comprendidas dentro de los límites económicos de la transmisión de la energía, a no ser que se agreguen nuevos consumos para los cuales el agua extraída de Titicaca sería esencial.

3.ª — Las obras necesarias para desarrollar la potencia final de 1.900 MW representan inversiones de tal cuantía que es poco probable que puedan ser abordadas por un solo país.

4.ª — La ubicación del centro de generación, al oriente del lago Titicaca, quedaría desplazado con respecto a los posibles centros de grandes consumos industriales.

Una forma racional de obviar los inconvenientes mencionados sería [illegible] su uso en riego e industrias, con creación de producción agrícola en las zonas actualmente áridas y con desarrollo de producción industrial en las zonas de abundantes minerales y otras materias primas, a más de los consumos subsiguientes de la población que allí se establezca.

3 — UTILIZACION DE LAS AGUAS DEL LAGO TITICACA CON DESVIACION HACIA EL PACIFICO

Las otras soluciones posibles para el aprovechamiento de las aguas del lago Titicaca consisten en desviarlas hacia el Pacífico. De las apreciaciones preliminares hechas, aparece que la solución más favorable es la desviación de las aguas por el curso del río Desaguadero, hasta su confluencia con el río Mauri, y seguir aproximadamente la ruta del ferrocarril de Arica a La Paz, mediante una aducción con varias elevaciones, para vaciarlas al valle profundo y encajonado del río Lluta, que sale al Pacífico al norte del puerto de Arica. La característica dominante de esta solución es el aprovechamiento múltiple de las aguas: para el riego, usos industriales y generación de energía. La ubicación de las centrales generadoras es favorable para la transmisión de la energía hasta los posibles centros de consumo, situados en Bolivia, Chile y Perú.

Al sur y norte del valle del río Lluta, en Chile y en Perú, se extienden terrenos hoy día árido, susceptibles de ser regados. La solución de aducir las aguas del lago Titicaca por el escarpado valle del río Lluta permite desarrollar ahí ventajosas centrales hidroeléctricas, en série hidráulica, con un aprovechamiento de altura de caída neta de unos 2,700 m., antes de repartir las aguas para riego, al pié de la cordillera de Huaililas, que constituye el cordón occidental de Los Andes en esa zona.

La solución de desviar de las aguas hacia el Pacífico contempla la depresión de 7 a 8 m. del nivel del lago Titicaca, para así poder disponer de 80 m³/seg. Se aprovecharía también el caudal del río Mauri, cuyos afluentes provienen de Chile y Perú. A fin de hacer llegar las aguas al borde occidental del altiplano, se las elevaría aproximadamente 350 m. por medio de una série de estaciones de bombeo. En esta forma, llegarían a la vertiente occidental de Los Andes, a más o menos 4.100 m. La potencia media neta total aprovechable, mediante la desviación de 80 m³/seg. hacia el Pacífico, sin considerar el aporte del río Mauri y con deducción de la elevación de las aguas, de las pérdidas de caída en las aducciones y los rendimientos de las máquinas motrices, puede estimarse en 1.700 MW. En atención a la regulación que proporciona el lago, el caudal sería permanente y permitiría obtener energía base que ascendería a unos 15.000 millones de KWH anuales.

A fin de apreciar la importancia relativa del riego con respecto a la generación de energía, se ha efectuado un cálculo de la equivalencia entre la producción agrícola de una hectarea de terreno regado y la

energía eléctrica generable con la misma cantidad de agua. Para este [illegible] de la producción agrícola anual de una hectárea de terreno regado en dichas zonas, y por otra parte, el precio medio resultante del kilowatt-hora de energía eléctrica que se obtendría con la misma cantidad de agua necesaria para regar una hectárea de terreno. La comparación de estas dos cifras da la equivalencia aproximada de 80.000 KWH por hectárea regada.

Con riego debidamente controlado y bien realizado, tal vez podría llevarse a cabo el riego de unas 100.000 a 200.000 Ha., ya que existen suficientes terrenos susceptibles de cultivo repartidos entre Chile y Perú. Con la equivalencia indicada, el riego de unas 150.000 Ha. representaría una compensación de alrededor de 12.000 millones de KWH anuales equivalentes, que resulta con el aprovechamiento complementario de las aguas desviadas hacia el Pacífico.

Por otra parte, en el altiplano boliviano y en el norte de Chile se encuentra la región del continente sudamericano que parece constituir el centro minero continental más importante, debido ya sea a la magnitud de los yacimientos actualmente en explotación, a la cantidad y variedad de los explotados, o a las posibilidades que se desprendan de la conformación geológica de la región.

En efecto, en ella se encuentran yacimientos metálicos de los más importantes del Mundo, de cobre y estaño; de sales, como nitratos, cloruros, boratos, yodatos y otras de sodio y potasio, que constituyen las principales reservas conocidas del hemisferio occidental; de azufre, y de un gran conjunto de minerales metálicos, como ser zinc, plomo, antimonio, níquel, cobalto y otros, que se encuentran ubicados en el altiplano boliviano.

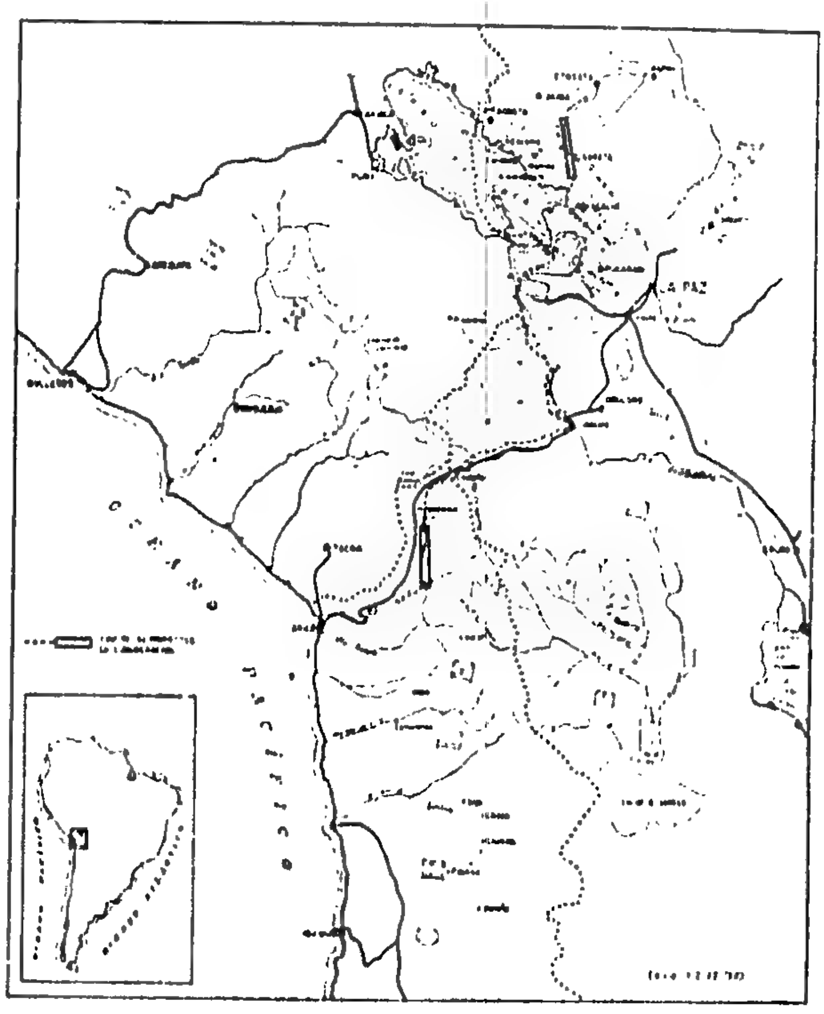
Para poder desarrollar la extracción y refinación de este valioso conjunto de materias primas es indispensable disponer, además de la energía eléctrica necesaria para los procesos de mecanización de la extracción, transporte, electrolisis, etc., de grandes cantidades de agua para los procesos de lavado y lixiviación, así como para atender al consumo requerido por la población.

Todo esto destaca la importancia que significa disponer de agua en la zona actualmente árida en que se encuentra tan gran acopio de materias primas. El caudal de 80 m³/seg. que se podría obtener del lago Titicaca, parece ampliamente suficiente para disponer de las aguas que hayan de necesitar las industrias, dada la magnitud relativa de los volúmenes que éstas requieren.

Para comparar las soluciones de desviación de las aguas al Atlántico y al Pacífico, convendría hacer, como en el caso de la utilización del agua para riego, un cálculo de la equivalencia económica en KWH de las disponibilidades de agua en los procesos industriales. Esto es difícil de realizar porque sería necesario estimar el monto de la producción y

analizar los procesos industriales de cada caso, para apreciar el consumo [illegible] productos fabricados, todo lo cual no es posible hacerlo a la fecha actual.

No obstante, como una simple apreciación, dado el importante conjunto de materias primas existentes y condiciones favorables para las



industrias, las disponibilidades de agua para estas representa una utilización complementaria que puede traducirse a lo menos en una cifra de KWH equivalentes del mismo orden que la estimada para el regadío.

En esta forma, con las salvedades expresadas y sólo para indicar una base de comparación, en el caso de la desviación de las aguas hacia el

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Pacífico, resultaría un aprovechamiento total alrededor de unos 39.000 [illegible] equivalentes, frente a la utilización de sólo unos 17.000 millones de KWH anuales de energía eléctrica, en el caso de la desviación de las aguas hacia el Atlántico. Esta comparación da como estimación que se obtendría 2.5 veces más energía equivalente, si se desvían las aguas hacia el Pacífico en vez de hacia el Atlántico.

Las principales consideraciones que se deducen de lo expuesto en este estudio son:

1.ª — Las aguas del lago Titicaca, desviadas hacia el Pacífico, tendrían aprovechamiento para generar energía, establecer industrias y regar terrenos actualmente áridos, en zonas situadas en el altiplano boliviano, en el norte de Chile y en el sur del Perú. Este aprovechamiento de las aguas, en términos de equivalencia económica, representa beneficios mucho mayores que la simple generación de energía.

2.ª — La potencia final por desarrollar de 1.700 MW no sería desproporcionada a las posibilidades de consumo, debido a que el empleo de agua en la agricultura e industrias de la región haría posible el desarrollo de nuevos e importantes consumos de energía eléctrica.

3.ª — Las centrales generadoras hidroeléctricas ubicadas en el valle del río Lluta quedarían muy cercanas al punto de concurrencia de las fronteras de los tres países y vecinas al centro de gravedad de los consumos actuales y futuros. Esto significará condiciones económicas favorables en cuanto a la transmisión de la energía hacia dichos centros de consumos.

4.ª — La realización de las obras necesarias para obtener la potencia final de 1.700 MW, que podrían hacerse por etapas, representaría inversiones que sería posible financiar más fácilmente con la concurrencia de los tres países, en atención a que Chile y Perú quedarían más directamente interesados, a causa de recibir las aguas, que si se obtuviera sólo energía eléctrica.

5.ª — La concurrencia de los factores: materias primas abundantes, agua, energía eléctrica, terrenos por regar, puertos y clima favorable, además de la posibilidad de recibir ahí el petróleo boliviano, hacen que esta región continental pueda llegar a ser un emporio económico de gran importancia.

I — CONCLUSIONES

En la región continental de Sud América, vecina al océano Pacífico, que comprende parte de los territorios de Bolivia, de Chile y de Perú, existe la posibilidad de desarrollar un gran recurso hidroeléctrico con las aguas del lago Titicaca, el cual está ubicado en el límite entre Bolivia y Perú, que actualmente no se aprovechan porque se evaporan.

[illegible] integral de estas posibilidades es indispensable [illegible] que se pierden por evaporación, que [illegible] lo cual puede lograrse reduciendo la superficie actual del lago mediante el descenso de su nivel medio.

Respecto a la salida de las aguas desde el lago, existen dos alternativas generales: su desviación hacia el Atlántico o hacia el Pacífico. De acuerdo con lo ya expuesto, la desviacion hacia el Atlántico, si bien permitiría un aprovechamiento hidroeléctrico mayor que la desviación hacia el Pacífico, involucra únicamente la generación de energía eléctrica. En cambio, la desviación de las aguas hacia el Pacífico significa su utilización también en otros fines, como los industriales y de regadío.

El desarrollo industrial y agrícola, que se obtiene al desviar las aguas hacia el Pacífico, permite absorber la cuantiosa energía que podría producirse.

Las necesidades de más energía, de mayores cantidades de alimentos y de mayores productos fabricados que tiene el Mundo, hacen extremadamente atractivo el proyecto de desarrollo integral de esta región continental. Además, este proyecto es especialmente atractivo por tratarse de una región que en la actualidad tiene bajo desarrollo industrial, poca producción agrícola y escasa población; pero abundantes recursos naturales.

La solución que se recomienda es de una magnitud tal que requerirá de los tres países interesados un esfuerzo económico considerable, que tiene que justificarse con un análisis detallado de la valorización de los beneficios que puedan obtenerse. Además, las informaciones técnicas y económicas que requiere un proyecto de esta envergadura abarcan estudios sobre topografía, geología, climatología e hidrología de la cuenca del lago Titicaca y zonas vecinas, como también sobre los posibles desarrollos industriales de aprovechamiento de las materias primas y los referentes a la calidad de los suelos y posibilidades de cultivos agrícolas. Todo este vasto conjunto de antecedentes y estudios preliminares exigirá el concurso de grupos técnicos especialistas, por el transcurso de varios años.

El proyecto mismo hidroeléctrico, que comprende la desviación de las aguas, las centrales generadoras y las líneas de transmisión, es en sí un proyecto complejo que requerirá también el concurso de numerosos técnicos y largo tiempo de confección.

Finalmente, la ejecución de las obras, por su magnitud, aún cuando puedan realizarse por etapas y emplearse los equipos de construcción más eficientes, demorará también varios años.

A pesar que este proyecto pueda aparecer ahora como desproporcionado con relación a la capacidad económica actual de los tres países interesados, el tiempo total necesario para su realización, de acuerdo con lo ya expresado, requiere iniciar desde luego los estudios preliminares.

[illegible]dentes necesarios para estos estudios de los proyectos de utilización de las aguas del lago Titicaca ya expuestos, es [illegible] Comisión Técnica Internacional, que debería constituirse de inmediato y abocarse al estudio del proyecto hidroeléctrico y de la economía general de la región continental, en donde sea susceptible de aprovecharse las aguas y la energía.

Resumen

Los autores se refieren al aprovechamiento internacional de las aguas del lago Titicaca, en relación a principios técnicos y económicos aplicados a este tipo de proyectos.

Indican que el aprovechamiento integral de las aguas afluentes al lago Titicaca, situado a 3.800 m. sobre el nivel del mar, tiene dos alternativas: la desviación de las aguas hacia el Atlántico o hacia el Pacífico, ya que actualmente se evaporan. Las soluciones que se han estudiado para la desviación hacia el Atlántico consultan extraer unos 20 m³/seg. del lago Titicaca, conduciéndolos hacia el río Beni y al Amazonas para la instalación de una potencia de 300 MW. Podría aumentarse el gasto aprovechable a 80 m³/seg. por medio de la disminución de la evaporación de las aguas en el lago, haciendo descender su nivel medio en 7 a 8 m. En esta forma y con aprovechamiento de la altura total de caída se podrían obtener unos 1.900 MW, con generación de 17.000 millones de KWH anuales.

Hacen los autores las siguientes observaciones a esta solución: que el agua del lago Titicaca no tendría otro aprovechamiento que para generar energía eléctrica; que la potencia total de 1.900 MW sería desproporcionada a las posibilidades de consumo, si no se desarrollan otros para los cuales el agua es esencial; que las obras para desarrollar esta potencia representan inversiones difíciles de ser abordadas por un solo país; y que la ubicación de las centrales generadoras quedaría desplazada con respecto a los posibles centros de grandes consumos industriales.

En cuanto a la desviación de las aguas hacia el Pacífico, expresan los autores que la característica dominante es el aprovechamiento múltiple de las aguas: para el riego, usos industriales y generación de energía. Los estudios preliminares indican que es posible llevar las aguas por el valle del río Mauri, mediante elevaciones sucesivas, conduciéndolas hasta 4.100 m. de altura y vaciarlas al profundo y encajonado valle del río Lluta, que sale al Pacífico al norte del puerto de Arica. La potencia aprovechable, descontando la necesaria para la elevación de las aguas, puede avaluarse en 1.700 MW, con generación de 15.000 millones de KWH anuales.

Los autores hacen consideraciones respecto a la importancia relativa del riego de terrenos áridos y han establecido una equivalencia económica aproximada de 80.000 KWH por hectárea regada, entre la producción

agrícola y la generación de energía con la misma cantidad de agua. [illegible] y en el sur del Perú existen suficientes terrenos susceptibles de cultivo y habría agua para regar unas 150.000 Ha., lo que representaría un aprovechamiento adicional de alrededor de 12.000 millones de KWH equivalentes.

Agregan que la región indicada del continente sud-americano puede considerarse como el centro minero más importante, pues se encuentran ahí yacimientos de cobre y de estaño de los más importantes del Mundo, de sales de sodio y potasio, y de un gran conjunto de minerales metálicos, como ser: zinc, plomo, antimonio, níquel, cobalto y otros. Para aprovechar este valioso conjunto de materias primas es indispensable disponer, además de la energía eléctrica, de grandes cantidades de agua. Para comparar las soluciones hacia el Atlántico y hacia el Pacífico, estiman que convendría hacer un cálculo de la equivalencia económica en KWH del agua empleada en los procesos industriales, en forma análoga a lo hecho para el agua destinada al regadío; pero esto no es posible hacerlo a la fecha actual. Como una simple apreciación, la estiman en una cifra de KWH equivalentes del mismo orden que la calculada para el regadío. Con las salvedades expresadas y para indicar una base de comparación, estiman un aprovechamiento de 39.000 millones de KWH anuales equivalentes, para la solución hacia el Pacífico, en comparación con la utilización de sólo 17.000 millones de KWH anuales, para la solución hacia el Atlántico.

Expresan los autores las siguientes consideraciones: que las aguas del Titicaca derivadas hacia el Pacífico tendrían aprovechamiento para generar energía, establecer industrias y regar tierras; que la potencia de 1.700 MW no sería desproporcionada a las posibilidades del consumo; que las centrales generadoras quedarían muy cercanas al punto de concurrencia de las fronteras de los tres países; que la realización de las obras mismas podría financiarse más fácilmente por los tres países, y que la concurrencia de los tres factores favorables ya expuestos hacen que la región continental pueda llegar a ser un emporio económico de gran importancia.

Como conclusión, los autores expresan que para la utilización integral de las aguas del Titicaca es indispensable recuperar aquella parte de lo que se pierde por evaporación, que se justifique económicamente, y recomiendan la solución hacia el Pacífico.

Esta solución es de tal magnitud que requerirá de los tres países interesados un esfuerzo económico considerable, que tiene que justificarse con la valorización detallada de los beneficios que puedan obtenerse. Para esto, se requerirán amplias informaciones técnicas y económicas sobre la cuenca del lago Titicaca y zonas vecinas, así como sobre los posibles desarrollos industriales de aprovechamiento de las materias

[illegible] posibilidades de cultivos agrícolas, todo lo cual necesita el [illegible] de grupos de técnicos especialistas. Igual [illegible] respecto al proyecto hidroeléctrico y a la ejecución de las obras.

Indican los autores que, a pesar que el proyecto podría aparecer ahora como desproporcionado con relación a la capacidad económica de Bolivia, Chile y Perú, en atención a lo expuesto, se requeriría iniciar desde luego los estudios preliminares. Con este fin preconizan la creación de una Comisión Técnica Internacional, que debería constituirse de inmediato y abocarse al estudio del proyecto hidroeléctrico de aprovechamiento internacional de las aguas del lago Titicaca, y de la economía general de la región continental de los tres países, en donde es susceptible de aprovecharse las aguas y la energía.

Résumé

Les auteurs étudient l'utilisation des eaux du lac Titicaca, d'accord avec les principes techniques et économiques applicables à ce genre de projets.

Ils indiquent deux solutions pour l'utilisation intégrale des eaux qui alimentent le lac Titicaca, situé à 3.800 mètres au dessus du niveau de la mer, ces eaux qui actuellement se perdent par évaporation, alors qu'elles pourraient être déviées, soit vers l'Atlantique, soit vers le Pacifique. Les solutions étudiées jusqu'ici pour la déviation vers l'Atlantique, contemplent l'extraction de 20 m³ sec. du lac Titicaca, pour les conduire vers la vallée du Beni et l'Amazone, avec la production d'une puissance de 500 MW. Il serait possible d'augmenter le débit utile à 80 m³ sec. grâce à une diminution de l'évaporation des eaux du lac, obtenue en abaissant de 7 à 8 mètres son niveau moyen. Dans ce cas et en utilisant la hauteur totale de chute, on pourrait obtenir 1.900 MW et produire 17.000 millions de KWH par an.

Les auteurs formulent les critiques suivantes à cette solution: elle ne permettrait d'utiliser les eaux du lac Titicaca que pour la production d'énergie électrique; la puissance totale de 1.900 MW serait hors de proportion avec les possibilités de consommation si l'on n'a pas d'autre emploi pour l'eau disponible; les travaux nécessaires pour développer cette puissance nécessiteraient l'immobilisation de capitaux dépassant les disponibilités économiques d'un seul pays, et finalement, les centrales se trouveraient fort éloignées des centres industriels prévisibles.

Par contre, la caractéristique essentielle de la déviation des eaux vers le Pacifique est, disent les auteurs, l'utilisation de l'eau à des fins multiples: l'irrigation, les usages industriels et la production de force motrice. Les études préliminaires indiquent la possibilité d'élever par échelons les eaux jusqu'à 1.100 m. d'altitude, de les conduire par le

[illegible] d'une debouchei dans la vallée profonde et [illegible] dans le Pacifique au nord du port d'Arica, [illegible] de celle nécessaire pour élever les eaux, peut être évaluée à 1.700 MW capables de produire 15.000 millions de KWH par an.

Les auteurs s'étendent sur l'importance relative de l'irrigation des terres actuellement arides et cela les conduit à établir, entre la production agricole et la génération de force motrice, une équivalence économique approximative de 8.000 KWH par hectare irrigué avec la même quantité d'eau. Ils ajoutent que les terres susceptibles d'être cultivées ne manquent pas au nord du Chili et au sud du Pérou et qu'il y aurait de l'eau pour irriguer 150.000 hectares, ce qui représenterait une utilisation supplémentaire équivalent à 12.000 millions de KWH par an.

Ils ajoutent que la région indiquée peut être considérée comme l'un des centres miniers les plus importants du continent sud-américain, avec ses grands gisements de cuivre et d'étain, de sels de soude et de potasse et une grand variété de minerais métalliques, de zinc, plomb, antimoine, nickel, cobalt, etc. Pour transformer au mieux ce riche ensemble de matières premières, il est indispensable de compter sur des grandes quantités d'eau, en plus de l'énergie électrique. Les auteurs suggèrent que pour comparer les avantages respectifs de la déviation vers l'Atlantique ou vers le Pacifique, il serait nécessaire de calculer l'équivalence économique exprimée en KWH de l'emploi additionel de l'eau dans les opérations de transformation industrielle, d'une façon analogue à ce qu'ils l'ont fait pour l'eau d'irrigation; mais ce calcul n'est pas possible dans l'état actuel des choses. A titre de simple approximation grossière, ils estiment qu'il y aurait une équivalence totale d'environ 59.000 millions de KWH annuels dans le cas de la déviation vers le Pacifique, contre seulement 17.000 millions de KWH annuels dans le cas d'une déviation vers l'Atlantique.

Les auteurs observent, que les eaux du Titicaca déviées vers le Pacifique pourraient être utilisés à produire de l'énergie électrique, à des emplois industriels et à irriguer des terres arides; que la puissance de 1.700 MW ne serait pas hors de proportion avec les possibilités de la consommation; que les centrales se trouveraient proches du point de rencontre des frontières des trois pays, Bolivie, Chili et Pérou; que le financement des travaux pourrait être reparti équitablement entre ces trois nations et que la concurrence de tous les facteurs favorables énumérés pourraient transformer cette région en un centre économique de grande importance continentale.

Les auteurs concluent que pour utiliser intégralement les eaux du lac Titicaca, il est indispensable de récupérer la partie qui se perd actuellement par évaporation et de justifier les travaux du point de vie économique; ils recommendent pour cette raison la solution de la déviation vers le Pacifique.

Cette solution est de telle magnitude quelle demandera de la part [illegible] économique considérable, qui devra se justifier par l'importance des bénéfices à attendre de sa realisation. Pour leur évaluation, il sera necessaire de réunir d'amples informations techniques et économiques sur la zone hydrographique du lac Titicaca et les régions adjacents, ainsi que sur les possibilités de développement agricole. Tout celà nécessitera le travail de groupes de spécialistes durant plusiers années. il en serà de même en ce qui concerne les études du project hydroélectrique et de l'éxecution des travaux.

Les auteurs indiquent que, s'il est vrai que le project peut paraître actuellement hors de proportion avec la capacité économique de la Bolivie, du Chili et du Pérou, il n'en est pas moins recommendable, pour les raisons indiquées, de commencer des maintenant les études préliminaires. Dans ce but, ils proposent la constitution d'une Commission Technique Internationale, qui devrait être crée au plus tôt et s'adonner à l'étude du project hydroelectrique de l'utilisation internationale des eaux du lac Titicaca et de l'économie generale de la région des trois pays interessés, susceptible d'utiliser les eaux et l'énergie produite.

SUMMARY

The authors make reference to the international utilisation of the water of the Lake Titicaca, in view of the technical and economic principles of this type of projects.

They mention that the total utilization of the incoming waters to the Lake Titicaca, which is located at an elevation of 3,800 meters over sea level, have two alternatives: its diversion to the Atlantic Ocean; as the water at present evaporates. The alternative which already have been studied in relation to the diversion to the Atlantic Ocean, contemplates the utilisation of around 20 m³ sec. from the Lake Titicaca, diverting this water towards the Beni river tributary of the Amazon, by means of which 300 MW can be developed. It is possible to increase the flow to 80 m³/sec. by means of a reduction in the evaporation of the waters of the Lake, for which it will be necessary to lower its average level by 7 to 8 meters; by this way and a total utitization of the obtainable head, 1,900 MW and an annual generation of 17 millions of KWH can be developed.

The authors have made the following remarks to this alternative: The water of the Titicaca Lake will not be used for any other purpose than the power generation; the total power developed of 1,900 MW will be out of proportion to the possibilities of its utilization, if there are no other load developments for which the water is essential; the volume of the necessary works for the development to said power capacity will re-

quire investments which are difficult to be taken out by one country, [illegible] stations will be located relatively out of place in relation with the future large industrial load centers.

In regard to the diversion of the water to the Pacific Ocean, the authors state that the main characteristic of such project would be the utilization of the water for multiple purposes: for irrigation, industrial uses and power generation. According to preliminary studies, the waters of the Titicaca can be diverted to the valley of river Mauri by means of successive pumping stations, up to an elevation of 4,100 m. and then thrown to the deep and narrow valley of Lluta river which reach the Pacific Ocean, North of Arica harbour.

The available power, deducting the necessary power for the elevation, can be estimated in 1,700 MW and the annual energy generation, in 15,000 millions of KWH.

The authors make several comments in relation to the relative importance of irrigation of arid lands and they establish an economic equivalence of approximately 80,000 KWH per irrigated hectare of land, if the agricultural production and energy generation that utilizes the same amount of water are compared. They also state that in the North of Chile and South of Peru there is plenty of land that can be cultivated and there is enough water for the irrigation of around 150,000 Ha, which will be equivalent to an additional utilization of around 12,000 millions of KWH.

They also state that the Bolivian Altiplane and the North of Chile can be considered as one of the most important mining centers of the hemisphere on account of the fact that there are located some of the most important copper and tin deposits of the world, as well as sodium and potasium salts and a great variety of metallic ore deposits, such as zinc, lead, antimon , nickel, cobalt and others.

In order to utilize this valuable group of raw materials, it is indispensable to have, besides the necessary electrical energy, large quantities of water. In order to compare the alternatives of diversion to the Atlantic Ocean and to the Pacific Ocean the authors think that it would be convenient to make a calculation of the economic equivalences in terms of KWH of water used in the industrial processes, in a similar way to what has been done for the irrigating water; but this is not possible to be done at present. As a guess they valuate this equivalent KWH figure as of the same order as the one estimated for irrigation.

With the above mentioned exceptions and with the only purpose of obtaining a comparative base, they estimate the total equivalent utilization of the diversion to the Pacific of around 29,000 millions of equivalent KWH per year and for the alternative of diversion to the Atlantic a utilization of only 17,000 millions KWH per year.

The authors conclude that the waters of the Titicaca diverted to [illegible] generation of power, in the mining industry and for irrigation of land, that the power of 1,700 MW will not be out of proportion to the load possibilities, that the location of the generating stations will be very close to the joining point of the borders of the three countries involved, that the financing of the works to be done would be more feasible by these countries on account of the water utilization and that the conjunction of the afore said favourable factors make this continental region to become an economical emporium of great importance.

The authors conclude that in order to obtain a maximum utilization of the Titicaca water it is necessary to recuperate the part of the water wasted by evaporation that economically justifies and they recommend the alternative of diversion to the Pacific Ocean.

This project will be of such magnitude that will require from the three countries involved a considerable economic effort which is to be justified by a complete valuation of the benefits to be obtained. For this, a wide technical and economic survey of the Titicaca basin and surroundings will be required, as well as a survey of the industrial, raw materials utilization and agricultural possibilities. All the above will require the work of a group of technicians and specialists for several years.

The same is valid in regard to the hydroelectric projects and to their construction.

The authors state that in spite of the fact that this project will appear today as out of proportion to the economic capacity of Bolivia, Chile and Peru, but in view of the afore said, it will require the immediate initiation of the preliminary studies. For this purpose they recommend the immediate creation of an International Technical Commission which should devote to the study of hydroelectrical project for the international utilization of the water of the Lake Titicaca as well as to the general economy of the continental region of the three countries where said water and power would be used.

CONFERÊNCIA MUNDIAL DA ENERGIA
WORLD POWER CONFERENCE

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RITTERSHAUSSEN (J.)
SANTA MARIA (D.)
Chile

PLANEACIÓN DE LA INDÚSTRIA DE GENERACIÓN ELÉCTRICA EN CHILE

Por JONH RITTERSHAUSSEN

y DOMINGO SANTA MARIA

COMITÉ NACIONAL CHILENO

I. — CARACTERISTICAS DEL PAIS

Chile tiene una geografía especial: gran extensión de norte a sur, desde la latitud 17° 30' hasta 56°, [illegible], entre la cordillera de Los Andes y el océano Pacífico, alturas variables sobre el mar, desde las costas hasta los valles y planicies a 1 000 m., además de los altos cerros de Los Andes, con cumbres cercanas a 7 000 m., gran extensión de costas, ríos de grandes pendientes, numerosas islas y canales en su parte sur, enormes diferencias de la precipitación atmosférica anual, desde 0 en las zonas áridas del norte hasta 5 m. y más en las zonas australes, clima templado, a pesar de las diferencias de altura y de latitud, y muy pequeña superficie de cultivo agrícola que en su principal parte requiere riego artificial debido a la distribución irregular de las lluvias durante el año.

La geografía de Chile impone al país la planificación de su desarrollo; el clima más benigno y la producción agrícola han determinado las zonas de mayor población y actividad. El aislamiento geográfico del país y la gran variedad de recursos y productos lo hace especialmente autárquico, pues en Chile se produce casi todo lo que el país necesita.

Las características expuestas determinan su división en regiones geográficas. Al considerarlas desde diferentes puntos de vista, como ser recursos naturales, producción, comunicaciones, clima, población, etc., los límites de las regiones geográficas son casi coincidentes. Para la planeación eléctrica del país, que se relaciona estrechamente con la economía general, se distinguen 7 Regiones Geográficas. Estas tienen características propias bien diferenciadas y son las siguientes, de norte a sur:

En la 1.ª Región, en el extremo norte, tiene terrenos áridos y gran- [illegible] todo pequeño, recursos hidráulicos en la parte alta de la cordillera de Los Andes. Los consumos eléctricos están dispersos en los diferentes puertos y en los centros industriales de la minería, sobresaliendo los del cobre y del salitre. El abastecimiento eléctrico se hace de preferencia con unidades térmicas.

La 2.ª Región Geográfica tiene producción mixta minera y agrícola, lo que origina consumos eléctricos diversificados; tiene recursos hidráulicos limitados en la alta cordillera, de poca agua, pero de grandes alturas de caída.

Las Regiones Geográficas 3.ª, 4.ª y 5.ª corresponden a la parte central del país, que es aquella en que se desarrollan las principales actividades comerciales, industriales, políticas y culturales, y en la cual vive el 80% de la población del país, aunque en extensión corresponde sólo al 10% de su superficie.

La 3.ª Región corresponde a la zona de Santiago y tiene ríos de régimen glacial, con caudales más o menos apreciables y grandes desniveles. La 4.ª Región, que es la zona de Concepción, dispone de apreciables recursos de energía: presenta ríos con características mixtas glaciales y pluviales y cuenta con yacimientos de carbón. La 5.ª Región, que corresponde a la zona de Valdivia, tiene grandes recursos hidráulicos y lagos de regulación de sus ríos, que presentan regímenes pluviales. Estas 3 Regiones Geográficas, aunque tienen características propias, quedan ubicadas en la llamada central del país y son las zonas de Chile en que se produce la mayor demanda de energía para usos generales industriales y agrícolas, si se prescinde de las industrias del cobre y del salitre del norte del país.

La 6.ª Región corresponde a la zona de los canales, islas y fiordos de Aisén, con muy escaso desarrollo y población; presenta grandes concentraciones de energía hidráulica a base de caudalosos ríos de régimen pluvial regulados en extensos lagos ubicados en la cordillera de Los Andes.

La 7.ª Región corresponde al extremo austral del país, de islas, canales y fiordos, con grandes extensiones cordilleranas de hielos continentales y pampas ganaderas en Punta Arenas y Tierra del Fuego. Esta región posee apreciables yacimientos de carbón, de bajo poder calorífico, yacimientos petrolíferos y limitados recursos hidroeléctricos.

2. DISPONIBILIDAD DE ENERGIA

Las fuentes de energía disponibles en Chile son: el carbón, el petróleo, la madera y los recursos hidráulicos.

Los carbones chilenos son del tipo bituminoso, presentándose en dos calidades: los de poder calorífico mediano, que se explotan en la zona de Concepción, y los de valores bajos, de la zona de Magallanes, casi sin explotación actualmente. La existencia estimada del carbón total

a la vista es de 61,5 millones de toneladas y una existencia sumada, a la [illegible] cifra en la cual corresponde a los carbones de Magallanes una existencia probable de 100 millones de toneladas.

Los yacimientos de petróleo se han descubierto recientemente en Tierra del Fuego. La reserva probable se estima, dentro del período inicial de perforación de pozos, en 6 millones de kilolitros, con una reserva cubicada de 1.5 millones de kilolitros.

Una cuota importante del consumo de energía en Chile proviene de la madera, aprovechada para producir calor. Se ha estimado que el área forestal total del país es más o menos 15 millones de Ha. El total del volumen de madera en pié se ha estimado en 1.815 millones de m³, de los cuales el 90% es de bosques naturales de las regiones del sur del país. El crecimiento anual de los bosques se ha apreciado en 20.7 millones de m³ y se ha calculado que Chile aprovecha un volumen anual de alrededor de 5,6 millones de m³.

En cuanto a los recursos hidráulicos del país, las cifras revisadas en 1952 del catastro de los recursos hidroeléctricos de más económico aprovechamiento, arrojan un total de más de 4 millones de KW de potencia para la duración del gasto de 95%, y de más de 12 millones de KW para la potencia correspondiente al promedio del gasto. Probablemente pueda obtenerse económicamente una potencia base de más de 10 millones de KW, al considerar la regulación posible del gasto que puede hacerse en los grandes lagos.

El resumen del catastro, que se indica a continuación, contiene sólo los principales recursos reconocidos. Para obtener el total del país, es necesario agregar a éste, otros recursos hidráulicos posibles, aun no individualizados o de relativa pequeña capacidad. Las cifras son las siguientes:

Regiones Geográficas	*Potencias base en MW para los gastos De duración* 95%	50%	*Promedios*
1.ª	28	70	81
2.ª	11	112	220
3.ª	1 118	2 880	3.931
4.ª	643	2 275	2.515
5.ª	706	2 065	2.216
6.ª	1 108	2 877	3.110
7.ª	77	186	213
Recursos del catastro	4 101	10.475	12.349
Otros recursos	1 179	2 105	2.461
TOTAL de Chile (año 1949)	5 280	12 580	14 810

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PLANIFICACION ELECTRICA

El Plan de Electrificación del País se ha orientado a atender a las demandas de consumo de energía existentes y a las previsiones para el futuro, en atención a las actividades y materias primas en cada región geográfica.

La existencia de pequeños recursos carboníferos y reducidos de petróleo, estando estos últimos en su etapa de explotación, frente a la existencia de grandes recursos hidráulicos, ha determinado basar preferentemente el abastecimiento de energía eléctrica en la utilización de los recursos hidráulicos.

Estos recursos están ubicados, en general, en los cursos altos de los ríos, antes de llegar estos a la llanura central donde sus aguas son aprovechadas para el riego. En la parte sur, quedan ubicados en el curso medio, a la salida de los lagos que regulan las aguas. Presentan caídas medianas y altas, y quedan a distancias relativamente cortas de los centros de consumo, los cuales corresponden en su mayor parte a los núcleos de población y de actividad de la llanura central y de la costa.

La planeación de las líneas de transmisión y distribución queda así bien determinada, pues se deriva del aprovechamiento racional de los recursos hidráulicos.

Su trazado debe unir las diferentes centrales generadoras con los principales centros de consumo, pero previendo el transporte de la energía de norte a sur y viceversa, especialmente para el futuro.

La Empresa Nacional de Electricidad S.A. (ENDESA) es la que ha desarrollado el programa general y tiene a su cargo el estudio, planeación y realización del Plan de Electrificación del País. Lo ha llevado a cabo en coordinación con las instalaciones existentes de otras empresas, a las cuales suministra energía eléctrica para su distribución. La ENDESA ha construido diferentes centrales hidráulicas, conforme a la planeación general y a la concepción de las regiones geográficas eléctricas. Estas tendrán, durante la primera etapa de la electrificación del país, cada una su propio abastecimiento de energía para atender a sus consumos.

La planeación de las obras se ha llevado a cabo basada en la construcción de 1 ó 2 plantas hidroeléctricas de capacidad adecuada para atender, en general, el abastecimiento de cada región geográfica, en combinación con otras plantas eléctricas, en aquellas partes del territorio donde existan.

Las actuales demandas de consumo determinan la necesidad de mayor generación, especialmente para abastecer la zona de Santiago y ciudades vecinas. Esta se destaca como el principal centro consumidor y tiene el sistema eléctrico más importante del país.

Las materias primas y las características geográficas han impuesto el desarrollo de un gran centro de industria pesada en la zona de Concepción y del puerto de Talcahuano, lo cual ha llevado a construir allí un nuevo sistema eléctrico, el segundo del país en importancia.

La zona sur de la llanura central que se encuentra en pleno desarrollo [illegible] tiene importantes recursos naturales. La ENDESA ha formado en esta zona un sistema eléctrico para satisfacer las demandas existentes y fomentar el desarrollo general de la producción.

Hacia el norte, en la provincia de Coquimbo, se ha establecido otro sistema eléctrico, destinado a atender tanto a las demandas actuales como a fomentar los consumos de la producción minera y agrícola en esa zona.

La planeación de la construcción de las centrales hidroeléctricas se ha hecho prefiriendo a las de menor inversión inicial o a aquellas de ubicación más favorable con respecto a los principales centros de consumo. En esta se ha tenido presente la posible electrificación de las líneas ferroviarias y la instalación de nuevas industrias grandes consumidoras de energía eléctrica.

La obra de la ENDESA comenzó en 1943. Adoptó el suministro uniforme con corriente alterna trifásica de 50 ciclos seg., el sistema tetrafilar de 220/380 V. para los consumos domésticos, industriales pequeños y otros, y los voltajes de 13.200 y 66.000 V. para entrega a los grandes consumidores, sean estos cooperativas eléctricas, empresas de distribución o grandes industrias. En la zona de Santiago existían instalaciones de distribución de la Compañía Chilena de Electricidad, al voltaje de 12.000 V., que se han conservado.

La planeación se ha realizado, hasta la fecha en la siguiente forma.

En la 1ª Región, a causa de los consumos concentrados en los puertos y en las instalaciones aisladas de la gran industria del cobre y del salitre y por ser muy reducidos los recursos hidráulicos, el suministro se realiza mediante centrales térmicas separadas, ya que las distancias y características geográficas no justifican por ahora, la construcción de sistemas eléctricos regionales.

En la 2ª Región se ha construido la central hidroeléctrica Molles, de gran altura de caída (1.150 m.), con red de líneas a 66.000 y 13.200 V., y una central diesel de alumbrado en la bahía de Guayacán, impuesta por las características hidrológicas de baja duración de los gastos de los ríos de esa Región. Este sistema está proyectado para abastecer a todos los consumos urbanos, agrícolas y mineros.

En la llanura central se han construido 3 sistemas principales, cada uno de ellos destinado, en un principio, a generar la energía necesaria para satisfacer las demandas de la 3ª, 4ª y 5ª Regiones. Sin embargo, conveniencias económicas y razones de seguridad de servicio han llevado ya a iniciar una interconexión parcial entre los 2 principales sistemas eléctricos, que corresponden a la 3ª y 4ª Regiones.

En la 3ª Región, la ENDESA ha construido 2 centrales: Sauzal, con estanque de regulación diaria, y Cipreses, con embalse de regulación, con 175.000 KW. entre ambas, que están unidas por líneas de 154.000 y 110.000 V. al centro consumidor de Santiago. Este contaba, desde hace

años, con 4 centrales hidroeléctricas y 2 termoeléctricas, estando obras [illegible] Valparaíso, todas las cuales pertenecen a la Compañía Chilena de Electricidad. La totalidad de las centrales de esta Compañía, las de la ENDESA y varias otras de menor potencia, pertenecientes a la gran industria, funcionan interconectadas abasteciendo de energía a toda la 3.ª Región.

En la 4.ª Región, la ENDESA ha construido la central Abanico (actualmente con 86.000 KW y en el futuro con 129.000 KW) y tiene en proyecto la central Lago Laja (152.000 KW), la cual quedará en serie hidráulica con la anterior y será una central de embalse, con gran capacidad de regulación. La central Abanico abastece de energía a toda la 4.ª Región, y en especial a la zona industrial de Concepción, por medio de una línea de transmisión de 154.000 V. y diferentes líneas de distribución, de 66.000 y 13.200 V.

En la 5.ª Región la ENDESA ha construido la central Pilmaiquén (actualmente con 21.000 KW y en el futuro con 35.000 KW), que abastece a la parte sur de esa Región, y tiene en proyecto la planta hidráulica Pullinque (45.000 KW), la cual se interconectará con Pilmaiquén y permitirá atender la parte norte y los futuros aumentos de demanda de toda la Región.

La 6.ª Región, que corresponde a la parte menos desarrollada del país, tiene abundantes recursos hidroeléctricos, especialmente adecuados para la instalación de grandes industrias. Actualmente los consumos son mínimos y por esta causa no se han hecho obras.

En la 7.ª Región, del extremo austral, los consumos se concentran en los núcleos de población, los cuales se abastecen con centrales térmicas.

Las diversas pequeñas centrales térmicas y hidráulicas de construcción anticuada, ubicadas en diferentes partes del país, tanto para servicio público como privado, se encuentran casi en su totalidad interconectadas con los sistemas regionales indicados, y se mantienen para su funcionamiento durante los períodos de máxima demanda y emergencia. Forman excepción las grandes centrales destinadas a satisfacer consumos de la minería.

1. — CONSUMOS DE ENERGIA ELECTRICA DE CHILE

En el último período desde 1939 a 1952, el consumo de energía eléctrica en el país ha aumentado en la forma que se indica en el cuadro siguiente, que muestra la generación proveniente de las tres principales fuentes de energía usadas: carbón, petróleo y derivados, y recursos hidroeléctricos, con un aumento de 72%, en el período de 13 años que se indica.

[illegible] ELECTRICA EN MILLONES DE KWH

Año	[illegible]	[illegible]	De [illegible] Industriales	Totales
1939	188	907	765	1.860
1940	214	982	766	1.962
1941	244	1.259	842	2.345
1942	274	1.285	845	2.404
1943	192	1.284	982	2.457
1944	244	1.286	1.050	2.580
1945	181	1.261	1.168	2.610
1946	234	1.190	1.089	2.513
1947	274	1.248	1.199	2.721
1948	239	1.258	1.376	2.873
1949	144	1.162	1.509	2.815
1950	220	1.045	1.632	2.897
1951	228	1.150	1.854	3.232
1952	283	1.093	1.823	3.199

Los aportes que la ENDESA ha hecho a la producción de energía eléctrica con las obras realizadas correspondientes al Plan de Electrificación del País, han sido los siguientes:

Año	Millones de KWH
1944	2
1945	11
1946	24
1947	32
1948	117
1949	344
1950	399
1951	514
1952	603

La generación hidroeléctrica de la ENDESA del año 1952, de 603 millones de KWH, es la mayor generación de instalaciones de este tipo, frente a 573 millones de KWH de la Compañía Chilena de Electricidad, que provee a la zona de Santiago, y a 354 millones de KWH de la mina de cobre de la Braden Copper Company, correspondientes a ese mismo año.

5 PLANEACIÓN PARA EL FUTURO

Las especiales características de las diferentes regiones geográficas eléctricas han conducido a la formulación del Plan de Electrificación del País, con tres etapas de construcción. La primera, en gran parte realizada y

[illegible] construcción de sistemas eléctricos regionales, para recibir la energía de una o dos centrales generadoras. La segunda [illegible] inician, comprende la interconexión a altos voltajes de los centros de gravedad de las centrales generadoras de energía eléctrica de cada una de las zonas, con el fin de transportarla en grandes masas de sur a norte durante las primaveras y veranos. En esta forma se aprovecharán racionalmente las características diferentes de los regímenes hidrológicos de los ríos glaciales y pluviales.

La tercera etapa, como continuación de la anterior, representa la etapa final de la electrificación del país y comprende, en general, la utilización integral de los recursos hidráulicos aprovechando las diferencias de los regímenes hidrológicos de los ríos a lo largo del país y las grandes capacidades de almacenamiento de agua en los embalses de los grandes lagos. Para lograrlo será menester desarrollar largas líneas de transmisión, de gran capacidad, a muy altos voltajes y instalar potencia de relativa baja duración hidrológica. En esta forma, la regulación proporcionada por tales volúmenes de agua de los lagos permitirá obtener energía de 95% de duración hidrológica para gastos cercanos a los promedios anuales.

6. CONSIDERACIONES SOBRE LA ELECTRIFICACIÓN DE CHILE

De la breve reseña hecha sobre la electrificación del país cabe destacar las siguientes directivas generales en que está basado su desarrollo:

1.ª — La concepción de regiones geográficas, determinadas por las características propias de la geografía, materias primas y productos naturales, población y desarrollo, conjuntamente con las disponibilidades de recursos hidroeléctricos.

2.ª — La casi exclusiva generación hidroeléctrica, en consideración a las disponibilidades de energía de las diferentes fuentes del país, consultándose sólo subsidiariamente centrales térmicas, para los efectos de atender consumos de punta y de afirmado de centrales hidroeléctricas aun no interconectadas.

3.ª — El aprovechamiento integral y múltiple de las aguas, con ejecución de las obras para una duración hidrológica tan baja como pueda justificarse económicamente, teniendo en vista las interconexiones entre las centrales generadoras de una misma región y, para el futuro, entre las diversas regiones geográficas. Se han instalado las centrales generadoras en los cursos altos de los ríos glaciales de la cordillera de Los Andes, antes de las bocatomas de los canales de riego, y en los cursos medios de los ríos pluviales después de los grandes lagos de regulación de las aguas.

4.ª — La normalización del sistema de suministro de corriente alterna trifásica de 50 ciclos/seg. y de los voltajes de distribución, a 220/380 V, a 13.200 V. (en algunas zonas a 12.000 V) y a 66.000 V, con planeación de todas las redes de distribución teniendo en vista las líneas y subestaciones primarias que se deducen de la planeación general derivada de las centrales hidroeléctricas de cada región geográfica.

CPYRGHT

Esta planeación completa de las centrales, subestaciones y líneas [illegible] [illegible] electivos, por cuanto se ha llegado a obtener altos factores de carga en los diversos sistemas que interconectan a las centrales hidroeléctricas y termoeléctricas existentes en Chile.

La planeación de las obras eléctricas a escala nacional es de gran importancia en los países poco desarrollados, como los de América del Sur, en los cuales, en general, no existen grandes instalaciones eléctricas. En consecuencia, estas deben proyectarse y construirse teniendo en cuenta la totalidad de los consumos, tanto los actuales como los futuros, a fin de realizar la electrificación en forma progresiva, con inversiones mínimas.

Es de suma importancia la coordinación total de la planeación eléctrica, desde las grandes centrales generadoras hasta las líneas de las redes urbanas y de electrificación rural, que permitan entregar la energía eléctrica a bajo precio no sólo a los grandes consumidores industriales, sino también a los diversos consumidores urbanos y agrícolas.

Resumen

Los autores destacan las principales características de las diversas zonas de Chile, indicando que al considerar al país desde los diferentes puntos de vista de los recursos naturales, producción, facilidades de las comunicaciones, clima, población, etc., se llega a regiones geográficas casi coincidentes. Para la parte eléctrica se distinguen 7 Regiones Geográficas de norte a sur del país.

Expresan que las fuentes de energía disponibles son los carbones, el petróleo, la madera y los recursos hidráulicos. Los carbones y el petróleo tienen una existencia limitada. La madera constituye una [illegible] importante en la producción de energía en forma de calor. Los recursos hidráulicos son abundantes. El catastro de los de más económico aprovechamiento [illegible] millones de KW de potencia base con 95% de duración hidrológica y unos 12 millones de KW de potencia para los gastos promedios. Los recursos totales posibles de aprovechar son mayores que estas cifras.

El Plan de [illegible] [illegible] [illegible] al desarrollo [illegible] [illegible] de instalaciones hidroeléctricas con el consumo [illegible] [illegible] transmisión [illegible] las diferentes centrales generadoras a los principales centros de consumo.

La Empresa Nacional de Electricidad S.A. (ENDESA) ha desarrollado el programa [illegible] [illegible] de Plan [illegible] [illegible] [illegible] [illegible] ENDESA [illegible] en [illegible] [illegible] [illegible] de [illegible] 200 [illegible] distribución y de entrega de energía a los grandes consumidores.

La ENDESA ha construido diversas centrales hidroeléctricas, que se [illegible] cada región geográfica con las grandes centrales térmicas e hidráulicas que existían, y además con las pequeñas de construcción anticuada, que se mantienen como emergencia para los períodos de máxima demanda.

Los consumos totales de energía eléctrica han aumentado de 1.800 a 3.199 millones de KWH en el período de 13 años, desde 1941 a 1952. El aporte de la ENDESA a la producción de energía eléctrica ha subido de 2 a 603 millones de KWH, desde 1941 a 1952.

El Plan de Electrificación comprende tres etapas: la primera ha sido la construcción de sistemas eléctricos regionales. La segunda, comprende la interconexión de los centros de gravedad de las centrales generadoras de cada una de las zonas con el fin de transportar la energía en grandes masas, según las épocas del año, en uno u otro sentido. La tercera comprende la utilización integral de los recursos hidráulicos aprovechando las diferencias de los regímenes hidrológicos de los ríos en las diferentes latitudes del país y las grandes capacidades de almacenamiento de agua en los embalses de los grandes lagos. Se podrá llegar así a obtener energía de 95% de duración hidrológica para gastos cercanos a los promedios anuales.

La planeación completa y racional de los sistemas regionales con sus centrales, subestaciones y líneas eléctricas, está dando resultados efectivos llegándose a obtener en ellos altos factores de carga.

La planeación de las obras a escala nacional es de gran importancia en los países poco desarrollados, donde no existen, en general, grandes instalaciones eléctricas, y éstas deben proyectarse y construirse en forma progresiva, considerando todos los consumos actuales y futuros, para obtener inversiones mínimas. Es de gran importancia la coordinación total de las obras, para poder entregar la energía a bajo precio no sólo a los grandes consumidores industriales sino también a los pequeños consumidores urbanos y agrícolas.

RESUME

Les auteurs font ressortir les principales caractéristiques des nombreuses zones du Chili, en indiquant qu'on arrive à des régions géographiques presque coïncidents, quand on les considère du point de vue des ressources naturelles, de la production, des facilités de communications, du climat, de la population, etc. Pour le développement électrique on distingue, du Nord au Sud du pays, 7 régions géographiques.

Ils font remarquer que les sources disponibles d'énergie sont: le charbon, le pétrole, le bois et les ressources hydrauliques. Le charbon et le pétrole ont une existence limitée. Le bois apporte, en forme de chaleur, une quote-part importante à la production d'énergie. Les ressources hydroélectriques sont abondantes. Le cadastre de celles dont l'utilisation est

le plus économique [illegible] plus de [illegible] millions de KW de puissance [illegible] [illegible] et de 12 millions de KW de puissance pour les débits moyens. Les ressources totales, possibles d'utiliser, sont plus grandes que les chiffres donnés ci-dessus.

Le Plan de l'Électrification du Pays a été orienté en vue de pourvoir d'énergie électrique, principalement au moyen d'installations hydroélectriques, avec le concurrent développement des lignes de transmission nécessaires pour unir les différentes centrales génératrices aux principaux centres de consommation.

La "Empresa Nacional de Electricidad S. A." (ENDESA) c'est l'entreprise qui a fait le programme général et est chargée d'étudier, de planifier et de réaliser le Plan d'Électrification du Pays, en coordination avec les installations existantes et qui appartiennent à d'autres entreprises. L'oeuvre d'ENDESA a commencé en 1940. Pour fournir d'énergie elle a adopté le courant alternatif triphasé de 50 cycles sec., avec le système quatre fils de 220/380 V., et les tensions de 13 200 et 66 000 V. pour les lignes de distribution et de livraison aux grands consommateurs.

ENDESA a bâti plusieurs centrales hydroélectriques, qui se trouvent interconnectées dans chaque région géographique avec les grandes centrales thermiques et hydrauliques qui existaient auparavant et en outre, avec d'autres plus petites d'ancienne construction qu'on garde comme réserve pour les périodes de grande demande.

Les consommations totales d'énergie électrique ont augmenté de 1.860 à 5.490 millions de KWH dans une période de 13 ans, depuis 1939 jusqu'à 1952. L'apport d'ENDESA à la production d'énergie électrique a monté de 2 à 645 millions de KWH depuis 1944 jusqu'à 1952.

Le plan d'électrification comprend trois étapes. La première a été la construction de systèmes électriques régionaux. La deuxième comprend l'interconnexion des centres de gravité des centrales génératrices de chacune des régions, afin de transporter l'énergie en grandes masses, dans un sens ou dans l'autre, selon les saisons de l'année. La troisième, comprend l'utilisation intégrale des ressources hydrauliques, en profitant les différences des régimes hydrologiques des rivières le long du pays et la grande capacité des grands lacs pour garder l'eau. On pourrait ainsi arriver à obtenir énergie ferme de 95 % de durée hydrologique pour des débits moyens annuels.

La mise en plan complète et rationnelle des systèmes régionaux avec ses centrales électriques, ses lignes de transport et postes de transformation est en train de donner des résultats effectifs, et on est arrivé à y obtenir des hauts facteurs de charge.

L'étude des oeuvres en grande échelle est d'une très grande importance dans les pays peu développés parce qu'il n'y a pas, en général, des grands installations électriques et celles-ci doivent se projeter et se construire en forme progressive en considérant toutes les consommations actuelles et futures, pour y obtenir des inversions minimes.

[illegible] importance est la coordination totale des oeuvres pou[r] [illegible] pays bas, pas seulement aux grands consom[illegible] industriels, mais aussi divers consommateurs urbains et agricoles.

SUMMARY

The authors emphasize the facts that Chile, looked from the point of view of natural resources, productivity, communication, facilities, climate, population and so forth, can be divided in several geographical regions, that almost coincide when they are looked separately from each of the above mentioned points of view. For the electrical planning, from North to South of the country, seven geographical regions have been considered.

Coal, oil, wood and hydraulic power are the available sources of energy. The availability of coal and oil are limited. Wood, as heat producer, contributes with an important proportion to the total consumption of energy of the country. The hydraulic resources are abundant. The survey of those of most economic utilisation show more than 4 millions KW of base power 95%, hydrological duration and 12 millions KW of average flow power. The total possible utilization amounts to a far larger figure.

The Electrification Plan of the Country has been directed towards the supply of electric energy, mainly by means of hydraulic power plants with the correspondent construction of transmission lines in order to connect the different generating plants to the main load centers.

The "Empresa Nacional de Electricidad S. A." (ENDESA) is the institution that has laid out the planning and studies and is in charge of the construction and operation of the works involved in the Electrification Plan of the Country, and its coordination with the existing plants of other utilities. ENDESA's activities began in 1944. She has adopted as standard the three phase alternating current of 50 cycles sec. and the four wire of 220/380 V system and the tension of 13 200 and 66 000 V for the distribution lines to small or big consumers.

ENDESA has erected various hydroelectric plants interconnected in each geographical zone to the previously existing big thermoelectric and hydroelectric plants and also to the obsolete small ones. The latter are only maintained to work during the periods of maximum demand.

The total consumption of electric energy has increased from 1,800 to 3,400 millions KWH during the period of thirteen years since 1939 to 1952.

The contribution of ENDESA to the generation of electric energy has increased from 2 to 605 millions KWH since 1944 to 1952.

The Electrification Plan is divided into three stages: The first one has been the construction of regional electric systems. The second one includes the interconnection of the gravity center of each zone generat-

ing plants with the aim of transporting the energy in large blocks in one [illegible] the seasons of the year. The third one includes the integral utilisation of the hydraulic resources making use of the differences between the hydrological regime of the rivers at the different latitudes of the country and the large water storage capacity in the reservoirs of the great lakes. Thus it might be possible to obtain 95% hydrological duration base energy with flows close to the annual average values.

The complete and rational planning of the regional systems with their generating plants, substations and transmission lines is showing effective results, as high load factors are obtained.

The planning of the electric projects at a national scale is of great importance for under developed countries, since in these countries there are, in general, no big electric installations.

The projects must be planned and constructed progressively taking into account the actual and future consumption in order to achieve minimum investments.

The total coordination of the projects is of great importance because in this way the energy will be delivered at a low price not only to the big industrial customers but also to the small ones in the city and on the countryside.

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BRITISH DEVELOPMENTS IN GAS TURBINES *

By Sir HAROLD ROXBEE COX

[illegible] FRAeS, Chief Scientist [illegible]

A. T. BOWDEN

[illegible] C. A. Parsons & [illegible]

R. J. WELSH

[illegible] English Electric Co. [illegible]

[illegible] by the British Electrical and Allied Manufacturers' Association

and Professor W. R. HAWTHORNE

[illegible] Professor of Applied Thermodynamics, University of Cambridge

BRITISH NATIONAL COMMITTEE

1. INTRODUCTION

The first gas turbine patent was granted in England to John Barber in 1791. Sir Charles Parsons in his Specification No. 6735 of 1884 in which he describes the principles of the reaction steam turbine also foreshadowed the design of the modern gas turbine. Despite these contributions of the 18th and 19th centuries, however, the practical development of the gas turbine belongs wholly to this century, and the present widespread activity is a growth of the last twenty years.

Many countries have contributed to the development of the gas turbine — Switzerland, France, Germany, United States, Sweden, Hungary. In some the original stimulus was the promise of the gas turbine as a prime mover for industry. This is notably so in the case of Switzerland. In others the spur was the attractiveness of the gas turbine as an aircraft engine. It was this that originally prompted gas turbine activity

* BRITISH DEVELOPMENTS IN GAS TURBINES — Introduction by Sir Harold Roxbee Cox, Gas Turbines for Use on Land and Sea by A. T. Bowden, and R. J. Welsh, Gas Turbines for Aviation by Professor W. R. Hawthorne.

in Great Britain and the United States. In the case of Great Britain there were initially two distinct streams, both with their beginnings in the 1920s. One stream, owing its origin to Dr. A. A. Griffith, is associated with research into axial compressors. The other, which swelled into a great river of endeavour, is forever associated with the classic work of Sir Frank Whittle.

It was in 1926 that Dr. Griffith produced at the Royal Aircraft Establishment an aerodynamic theory of blade design based upon the flow past aerofoils as distinct from the flow through passages. This theoretical work led to experiments with model axial compressors which did not, however, get into its stride until 1936. On the work that was done from that time onward at the Royal Aircraft Establishment, however, with rotors built by a number of British firms, the modern design techniques used in Great Britain for axial flow rotors were founded. A close association developed between the Royal Aircraft Establishment and the Metropolitan-Vickers Company in the years immediately preceding the war which led ultimately to the design and construction by that Company of the Beryl aircraft engine. In those pre-war years also the other steam turbine manufacturers were concerning themselves with gas turbine design. The first British gas turbine of the industrial type: the Parsons 500 H.P. unit, was in fact designed in 1938 though, through the war, it did not run until 1945.

The greatest influence, however, in British gas turbine progress was Whittle. Whilst still a cadet at the Royal Air Force College, Whittle described in a thesis in 1928 the possibilities of jet propulsion and of gas turbines. Eighteen months later he conceived the idea of using the gas turbine for jet propulsion, and it is this association of the gas turbine and jet propulsion which constitutes the chief novelty of his remarkable work. His first patent was dated January 1930, and his scheme embraced compressors of both the axial and the centrifugal kind. The experimental engines which he subsequently built employed, however, centrifugal compressors, and he achieved during the war years, as a result of a wholly exceptional combination of scientific ability, engineering skill and determination, a series of engines which made their mark on history. Their ultimate development was by the Rolls-Royce Company, and culminated in the Nene and Tay power plants.

Whilst the centrifugal compressor type of engine was easily the first to get into service, the axial compressor engine was steadily progressing, and today, for military aircraft purposes, the centrifugal engine has been overtaken in performance though there is still a case for its use in civil aircraft because of the robustness of the centrifugal impeller.

The intensive development of both kinds of aircraft engine during the war and the intensive development, particularly of the axial type, since, has done more than place Great Britain well ahead of all other

countries in aircraft gas turbines. It has given a big impetus in Great Britain to the development of gas turbines for other purposes, and much of the aerodynamic, thermodynamic and general design progress achieved under the stimulus of war and defence has been applicable to the industrial gas turbines which have been the objectives of a not inconsiderable effort since the war ended. The progress made in axial compressor and turbine design for aircraft engines is readily applicable in the industrial applications, and despite the swing away from the centrifugal compressor, an attempt is being made to apply the best aircraft practice to an industrial centrifugal compressor project in which the space restrictions of aircraft installation do not apply.

Despite the characteristics which they have in common, however, in others the industrial and aircraft gas turbines differ widely. Probably the most obvious difference is in length of life required, and this means that in the early stages of its development the industrial gas turbine will tend to work at lower temperatures and with more generous arrangements of combustion space. Later, however, it will probably be possible to use systems of cooling more readily in some industrial gas turbines, and this may elevate their performance in a way which would scarcely be possible in the confined space permitted to the aircraft gas turbine.

An important factor in the development of the gas turbine in Great Britain is the collaboration between Government and industry. Not only has a great deal been accomplished through Government Departments placing development contracts with firms, but the Government's National Gas Turbine Establishment does valuable research work which is freely available to the gas turbine firms. There is, too, an admirable spirit of co-operation between all the firms and research establishments, Governmental and otherwise, in the gas turbine field. This is exemplified by the existence of committees comprising industrial and Governmental representation in which individual and common problems are freely discussed and in which advice and help are freely exchanged.

We in Great Britain are concerned with all applications of the gas turbine. In addition to its application to aircraft, which so far we have exploited further than the others, we are concerned with gas turbines for electrical power generation, for railway locomotives, for automobiles, for ships, and for auxiliary and pumping duties. Whilst the outstanding problem of the aircraft gas turbine, high altitude operation, has no counterpart in the other applications, they have their own severe problems, primarily concerned with burning fuels far less amenable than distillate oils. In Great Britain we are working on the combustion of residual oils and of solid fuels, and are making progress on both fronts. We are working on open cycle engines and on closed cycle engines, and we are probably covering a greater range of gas turbine activity than any other country in the world.

In the rest of this paper an attempt is made to indicate the range of this activity though of necessity the descriptions lack detail. In particular, no attempt has been made to describe the great achievements in the production of heat resisting materials in Great Britain without which the early engines would not have been possible, work which has since kept pace with the demands of design. Nor has any attempt been made to define the achievements of the scientists behind the engineers, whose development of aerodynamic techniques has not only put design on a sound basis but has pointed the way to increased efficiencies.

2. GAS TURBINES FOR USE ON LAND AND SEA

The energy now being devoted in Great Britain to the production of industrial gas turbines may be gauged from the fact that there are no fewer than thirteen separate firms engaged in the manufacture of complete industrial units: this is more than in any other country and nearly as many as in the rest of the world combined. As might be expected, these firms have some notable achievements to their credit including : —

The first gas turbine ship — powered by a Metropolitan-Vickers engine.

The first Atlantic crossing solely under the power of a marine gas turbine, made by the British tanker "Auris" with a British Thomson-Houston gas turbine.

The most powerful marine gas turbine yet built the Rolls Royce 6,000 H.P. R.M. 60.

The first closed cycle gas turbine to run on peat, built by J. Brown & Co., of Clydebank, and the first open cycle to run on peat was built by Ruston & Hornsby.

The first gas turbine automobile, made by the Rover Car Company.

British gas turbines for industrial, traction and marine use cover a wider range of powers and types than do those of any other country, and in the following section of the Paper an attempt has been made to give a faithful cross-section of the work of British gas turbine manufacturers. It cannot profess to be a complete record of all the work that has been or is being done, but does show clearly that all useful fields are being fully explored.

2.1 *Industrial Types*

These are being made in a wide range of powers, from the 50 H.P. Rover "Neptune" engine weighing only 100 lbs. (45.5 kg.). Fig. (1), and intended chiefly for fire pumps and emergency electric generators, to the 20,000 kW. "English Electric" gas turbo-alternators intended for central power station service.

Intermediate powers are well catered for by units such as the Ruston & Hornsby 900 kW set which is now in regular production as a standard model, one example being run under exhibition conditions at the 1953 Engineering Marine and Welding Exhibition in Olympia, London, where it supplied a large part of the power and light for the whole exhibition. Fig. (2). This gas turbine has been designed with particular emphasis on ease of maintenance; the whole turbine and compressor assembly can be opened up and inspected within two hours of shutting down. An interesting feature of this plant is that the standard units of which it is composed can be re-oriented at will, so that the air inlet, exhaust outlet, etc., can be arranged to face whatever direction may be most suitable for any particular installation. The governor can be adjusted by hand to give whatever speed droop may be required for parallel operation with any existing plant.

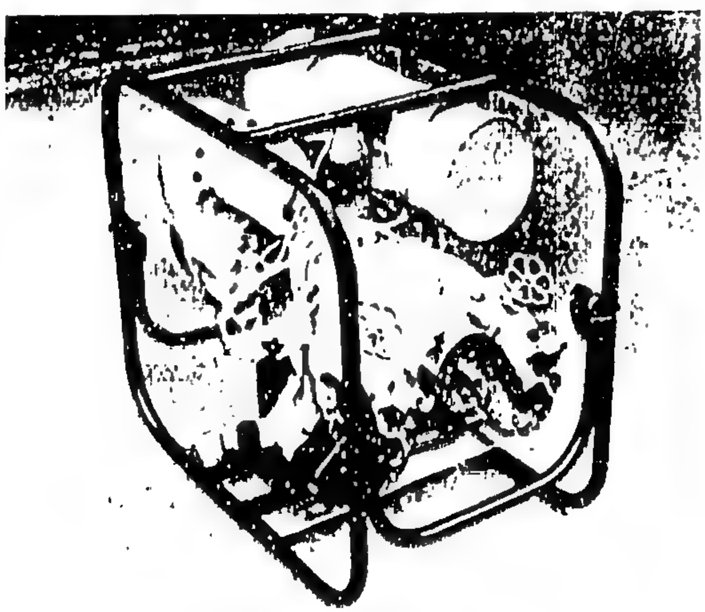

Fig. 1 — "Neptune" — A Rover Sigmund portable fire pump unit delivering 500 g.p.m. The turbine develops over 60 b.h.p. and the whole unit weighs less than 200 lb., complete with fuel for 1/2 hour full throttle operation.

Another unit is the Allen 1,000 kW set. This engine has a separate [illegible] light and compact — weight, 8 tons — overall height, including heat exchanger, 7 ft. It was primarily designed for the Admiralty as a marine auxiliary set, and allowances were made for long inlet and exhaust ducting. It has very good governing characteristics, and full load can readily be thrown on or off without risk of overspeed or stall.

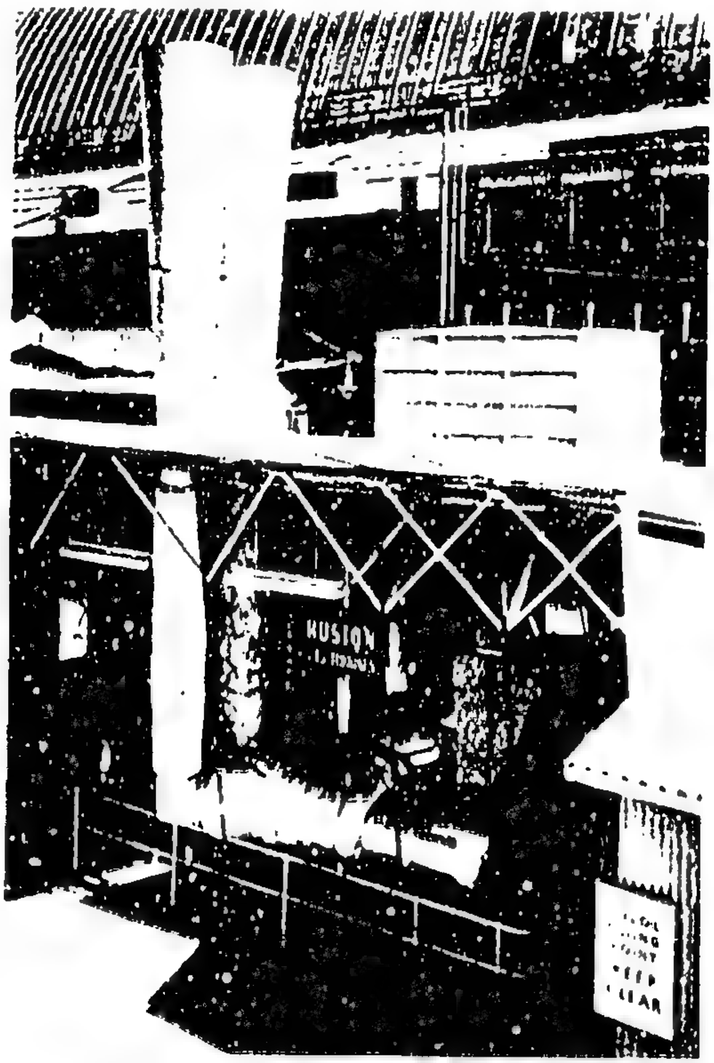

Fig. 2. — [illegible] kW Ruston & Hornsby gas turbo-alternator

Both of these machines have compressed-air-cooled rotors and stators; this [illegible] temperature and stress conditions in these parts, and enables the engines to be put on full load within five or ten minutes of starting from cold. It also avoids the need, so troublesome with early types of gas turbine, of having to keep machines rotating slowly for some hours to cool down after cutting off fuel at the end of a run.

In addition to the unit mentioned above, Messrs. W. H. Allen are producing a 150 kW gas turbine driven alternator. This is an emergency set primarily designed for British Admiralty but also suitable for stand-by and peak load purposes. The advantages over a high speed diesel lie in its small bulk, light weight, mechanical simplicity and cheapness. The unit employs a centrifugal compressor and radial inward flow turbine. The generator is driven at 3,000 r.p.m. through Allen-Stoeckicht epicyclic gearing.

In the 2,000/2,500 kW class units of different types have been made or are being developed by five separate firms, English Electric, Metropolitan-Vickers, Parsons BTH., and Brush

The English Electric set is distinguished by the use of an axial-cum-centrifugal compressor which makes the whole engine particularly small and light in weight, features of particular value in many applications, including up-country installations in undeveloped areas.

The Metropolitan-Vickers 2,000/2,500 kW gas turbine is one of the designs specially developed by this firm for industrial applications; this basic design is capable of adaptation to suit a wide range of requirements and has been applied to electricity generation (both base load and stand-by), locomotive traction and power generation from gaseous fuel. The Beryl and Sapphire aircraft engines, the naval boost gas turbines and the original generating set brought into industrial service in 1948 illustrate the wide background of experience possessed by this firm.

The Parsons 2,500 kW gas turbine is another machine of advanced design embracing separate compressor and work turbines. Quick starting and ease of inspection are particular features of the design. The work turbine is directly coupled to the alternator at 3,000 r.p.m. or 3,600 r.p.m. according to the frequency required. The same unit can be used with or without heat exchanger, without alteration to the machine components; in the former case it can be supplied as a self-contained packaged unit complete on its own bedplate

The Brush Co.'s 2,500 kW gas turbine, like the Parsons machine, has an output shaft running at 3,000/3,600 r.p.m. and will, therefore, be suitable for direct coupling to either 50 cycle or 60 cycle alternators without the use of any gearing. The estimated time to bring, to full load from cold is about five minutes.

The B.T.H. Co. has under construction two 2,500 kW gas turbo-alternator sets for Nairobi South Power Station, Kenya. The gas turbine here compared favourably with other types of prime movers because no cooling water is required except a small amount for lubricating oil and alternator air cooling. These gas turbine sets are single line sets in which one turbine drives the compressor directly and the alternator through speed reducing gears. A heat exchanger is incorporated in the cycle. An interesting feature is the single combustion chamber which is mounted vertically at the side of the set and bolted direct to the bottom half casing of the turbine.

The compressor, which is of the centrifugal type, has 4-stages. During a seven weeks test period, a set was run for about 600 hours. The testing included operation of some 300 hours on boiler oil without any loss in output or efficiency.

It is in the larger sizes of gas turbine, 10,000 kW and above, that British manufacturers show the greatest individuality in their choice of cycle and general design features.

The John Brown-Escher-Wyss design, of which a 12,500 kW example is being installed at Dundee, operates on the closed cycle — as also does a 700 kW unit being made by the same firm for generating power from waste heat at a Coventry gas-works.

The Metropolitan-Vickers 15,000 kW set, one example of which is in service with the British Electr y Authority in their Trafford power station, differs from any of its open cycle contemporaries by having the alternator driven from the same shaft as the L. P. compressor, thus permitting the H. P. compressor turbine assembly to be a higher-speed, smaller and more efficient unit which is fully stressed only under overload conditions.

The Parsons 10,000 kW and 15,000 kW gas turbines, on the other hand, have the alternator coupled to the same shaft as the H. P. compressor, advantages of this being that the thermal efficiency is better maintained at part-load and the performance of the set is less sensitive to changes in atmospheric ambient temperature

The English Electric 20,000 kW set differs from both these other units by having no heat exchanger, adequate thermal efficiency being obtained by the use of a higher pressure ratio This arrangement permits of a neat layout in the station

All design being a matter of compromise, each of these schemes have advantages and disadvantages for different applications which means that potential users of gas turbines in the higher power bracket have, in Britain, a choice between machines of quite widely different characteristics

2.2 Traction

Although for some years to come it is doubtful whether the gas turbine as applied to the locomotive will reach the same efficiency levels as a diesel engine under similar circumstances, the possible use of a cheaper grade of oil fuel and the saving in lubrication costs should offset to a considerable extent the superior efficiency of the diesel engine. Most locomotives work well below their maximum rated output for a considerable part of their useful operating life and in this regard the gas turbine operating under part-load conditions is at some disadvantage in comparison with the diesel engine. Nevertheless, in a unit specially designed for locomotive operation, this could be to a great extent offset by a proper selection of the desgn point. Under such circumstances the choice between diesel and gas turbine will lie in operating characteristics, reliability and maintenance, and only time will determine the true balance.

Fig. 3 — 3,000 H.P. Metropolitan-Vickers locomotive gas turbine

Metropolitan-Vickers have evolved a 3,000 H. P. traction version of their 2,000 kW 2,500 kW gas turbine and one unit of this type was incorporated in a M-V gas-turbo-electric locomotive put into service by British Railways in April 1952. This locomotive is remarkable in many ways; it is more powerful than any other locomotive in Britain, and is really intended for countries with heavier trains and steeper gradients. This particular unit running in Britain has, indeed, had the turbine deliberately "spoiled", lest it should inadvertently develop more power than would be safe to use on British railroads.

When the gas turbine on this locomotive was opened up for inspection in February 1953, after 75,000 miles, it was found to be in perfect condition throughout and was re-assembled without modification or repair; the bearings were put back exactly as found. A photograph of the power unit is shown in Fig. (3).

While Britain is conscious of the potential use of the oil-burning gas turbine locomotive, the possibilities of using coal have not been lost

[illegible] of [illegible] Fuel and Power have placed a contract with C. A. Parsons in conjunction with the North British Locomotive Company [illegible] coal-burning gas turbine locomotive. Fig. (4).

The locomotive is a single unit carried on two sixwheeled bogies, with the power transmitted mechanically from the turbine to four of the six axles. The turbine is supplied with clean air, which after being compressed is heated in an air heater. The hot clean exhaust air from the turbine is used as preheated combustion air for the coal fired combustion chamber of the air heater. The fuel costs per drawbar-hp-hr. for this locomotive should be considerably lower than for any coal-fired locomotive yet built.

2.3 *Road Transport*

Until quite recently the feeling was general that small gas turbine units suitable for automobile requirements must suffer because of the low Reynolds numbers involved, but there is little doubt now in the light of the work which has been done in Great Britain and elsewhere, that insofar as the efficiency of compressor and turbine components is concerned, no insuperable barrier exists. Small compact and efficient rotating elements can in fact, be made either on orthodox principles or by the use of inward radial flow turbine wheels. Demonstrations already made indicate that as far as transmission and operation are concerned, the gas turbine fits quite readily within the present automobile's structure.

The first gas turbine automobile in the world was a Rover sports model fitted with a Rover gas turbine of a type developed primarily for road transport, but now found to have more immediate uses in a wide range of diverse applications, including boat propulsion, starting units for larger gas turbines, portable generating sets, portable fire pumps, portable air compressors, marine auxiliary purposes, and earth-moving machinery.

The Rover automobile installation gives a convincing demonstration of the torque converter characteristics inherent in any free-power-turbine type of gas turbine. The gear box through which the turbine drives the road wheels has only one forward ratio and one ratio in reverse, yet from a standing start it can achieve an average speed of over 95 m.p.h. (150 k.p.h.) over the first mile. This is the characteristic that makes gas turbines so suitable for direct mechanical drive on all types of traction application, including railroad locomotives of even the highest powers.

As is well known, the automobile is notoriously a partload machine and it is under such conditions of operation that an efficient heat exchanger becomes a "must" for the automobile gas turbine, if it is to realise an acceptable standard of efficiency in operation.

Only the briefest mention may be made of the work undertaken in Britain on heat exchanger development, including both the recuperative type and the more attractive, although infinitely more complicated, rege-

[illegible] type [illegible] date is encouraging and there seems little doubt but that when a cheap and efficient heat exchanger is forthcoming, [illegible] of the gas turbine as applied to the automobile will be so improved as to make it competitive with the larger types of piston engine.

2.4 Marine

Marine propulsion is a hard taskmaster and makes insistent demands on economy of operation and reliability in service. Breakdowns are probably more costly than in any other form of transport and delays in port, even if of short duration, may largely offset any economy which might otherwise be made on fuel consumption. Accordingly -- while this is undoubtedly an attractive application — it is also one which calls for simplicity of design, economy of operation and low maintenance. Here the gas turbine is in strong competition with the well established diesel engine, particularly since the latter is now burning residual fuel with considerable success.

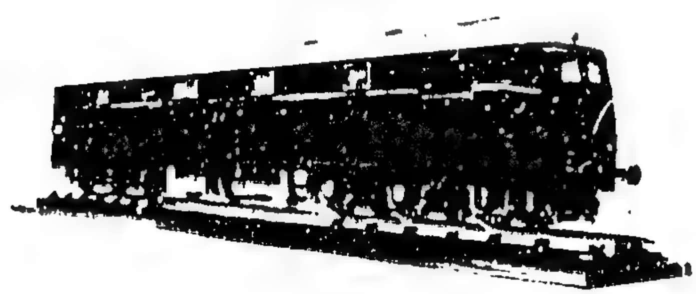

Fig. 4 — Parsons North British Locomotive Co., 1,800 H.P. coal fired gas turbine locomotive

When Motor Gun Boat No. 2009 of the Royal Navy put to sea in July 1947, she was the only gas turbine propelled ship in the world, and in her first few weeks of operation many demonstration trips were given to hundreds of engineers of all nationalities. The Metropolitan-Vickers "Gatric" gas turbine as installed, was rated at 2,500 H.P. and was the forerunner of larger M-V marine turbines of the same type. A number of turbines rated at 4,500 H.P., supplied to the British Navy and on order for the U. S. Navy, show an improvement in power weight ratio and in thermal efficiency of 22% on the figures of the "Gatric" engine.

A British ship, the tanker "Auris" belonging to the Anglo-Saxon Petroleum Company, was the first merchant vessel to have a gas turbine as one of her main engines. This engine was made by the B. T. H. Co., in Rugby and was installed in place of one of the four diesel-electric units

[illegible] was at first equipped. Up to the time of preparing this Paper (July 1953), this installation had completed over [illegible] at sea, including one crossing of the Atlantic during which the diesels were kept stationary and the vessel proceeded under gas turbine power alone. The high pressure turbine has been opened up for inspection and the blading found to be in good condition. At the only annual overhaul to have taken place up to the time of writing, the combustion chamber alone was partly dismantled, examined and re-assembled as before. The Anglo-Saxon Petroleum Company have now ordered a new 8,000 H.P. vessel with gas turbine power throughout.

The smaller type of marine gas turbine, for harbour launches and the like, is represented in Britain by the Rover Company's "Aurora" and projected "Snowdon" models of 120 H.P. and 300 H.P. respectively. These are free-power-turbine types of machines which are built both with and without heat exchangers. Their compactness and lightness may be gauged from the fact that the "Aurora" weighs only 150 lbs. (68 kg.) dry. Units of an early 200 H.P. "Snowdon" type have been supplied to the British Navy for tests both ashore and afloat.

The highest power of marine gas turbine under development anywhere in the world is the Rolls-Royce R. M. 60, a 6,000 s.h.p. unit of lightweight type especially designed to retain its high efficiency at low powers — and thus give the vessel a high endurance (i.e. a long mileage without re-fuelling) under cruising conditions. This engine (illustrated in Fig. 5) operates on a true compound cycle with intermediate power take-off. Test bed operation has borne out the original assumption that a compound marine gas turbine built on aeronautical lines gives a light and compact plant of great flexibility, capable of rapid starting and easy manoeuvring. There has been no insuperable problem in matching the components or in combustion at high pressures.

To obtain sea-going experience with the compound gas turbine, as a necessary prelude to the consideration of this form of propulsion for large naval craft, two R.M. 60 engines are shortly to be installed in place of the original propelling machinery in H.M.S. Grey Goose. Two R.M. 60 engines are also being supplied to the U.S. Navy.

2.5 *Fuels*

British manufacturers are convinced that the future of the industrial gas turbine will largely depend on the achievement of satisfactory and reliable operation in regular service on cheap types of fuel.

The troubles arising from the deposition of ash from the residual oil fuels, on turbine components working at high temperatures, have been fully discussed in the literature, and the intensive work which has been

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and is now being undertaken by industrial concerns the National Gas [illegible] Admiralty the Oil Companies and under far reaching contracts sponsored by the Ministry of Fuel and Power is already bearing fruit.

More recently, realising the place which the burning of solid fuel may hold in future gas turbine development the Government is promoting investigations into the problems associated with the use of coal and peat. This work covers many different applications in both the closed and open cycle type of gas turbine and while much remains to be done, it may be recorded that both types have operated on both fuels, and indeed an experimental closed cycle plant has operated for over, 1,000 hours on peat.

In addition, projects are now in hand for the combustion of natural gas, sewage gas firedamp (methane in coal mine ventilating air), blast furnace gas, ammonia (for a special chemical process) and brown coal.

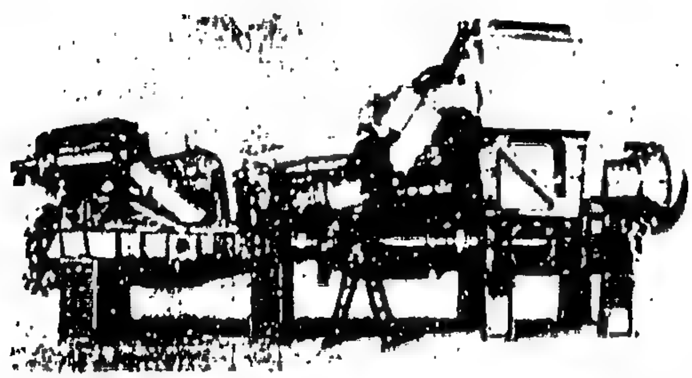

Fig. 5 — Complete assembly of Rolls Royce R.M. 4G marine gas turbine

2.6 *General*

With so many turbine builders some of whom are engaged on the production of several models it has clearly been impossible to mention all the gas turbine work in progress in Great Britain. Lack of space has prevented even the briefest mention of several firms whose combined efforts on gas turbines have made, and are making, a very considerable contribution to the overall development. These firms include the General Electric Co., Centrax Ltd., Harland & Wolff Ltd., Blackburn & General Aircraft Co. Ltd. and of course the marine engineering works of the various Shipbuilders whose gas turbine research activities have been pooled to such good effect at the Parsons and Marine Engineering Turbine Research and Development Association at Wallsend on Tyne.

[illegible] to generalise on the work of so many teams it may be said that the principal trends in the development of the industry [illegible] in the directions of extending the range of fuels and making still more use of air cooling for hot components with the twin objects of economising in the use of expensive materials and of utilising higher gas temperatures without any sacrifice in plant life or reliability.

It is now realised that, although there are many duties which the gas turbine may ultimately perform, only some of these are practical commercial propositions at the present time; others are future possibilities that depend on such things as the achievement of satisfactory operation with cheap fuels. This realisation has conditioned the whole trend of gas turbine development in Britain, and the day is past when a designer aimed merely at producing a good gas turbine. Although every endeavour is made to improve component efficiency, to-day's designer must keep clearly before him the fact that his machine is intended for one or more specific uses, each of which has its well defined requirements. Simplicity, low production cost, and ease of maintenance, are other items that have assumed a new importance now that the gas turbine is becoming a practical commercial proposition for an increasing number of purposes.

3. GAS TURBINES FOR AVIATION

The art of aircraft propulsion is now entering its most fascinating phase. This phase is the reduction to practice of the more promising of the ideas which have proliferated following the success of Sir Frank Whittle's original concept. The analysis of these ideas has occupied much attention in the last ten years. A typical example of such analysis was presented at the last World Power Conference by Owner and Hooker who discussed the performances of the turbo-jet, turbo-prop, ducted fan and ram-jet.

Where advantages have been clearly indicated by analysis, industry in Britain has been quick to exploit them. Examples of this are seen today in the axial flow turbo-jets of twice the pressure rations of early centrifugal jet engines and lower specific weight, in the small turbo-prop engines (e.g. the Dart, Mamba and Eland) and their application to aircraft (e.g. the Viscount). The Comet family of aeroplanes is an outstanding further example of timely enterprise based on studied calculations and the concept of the gradual evolution of an aircraft type.

Even where the lines of development have not been surely seen useful experiments have been made. For example, both Power Jets and Metropolitan Vickers built experimental ducted fan engines. The Bristol Theseus and Rolls-Royce Clyde were early explorations of the possibilities of two shaft engines. Armstrong-Siddeley experimented with

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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Avon	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

September 1953 *TURBO-PROPELLER ENGINE* [illegible]

Engine	Manufacturer	[illegible] S.H.P.	SPEC. FUEL CONS. LB./S.H.P./HR. T.O.	SPEC. FUEL CONS. LB./S.H.P./HR. [illegible] M.P.H.	Net Dry Weight Lb. (Excluding Prop.)
Clyde	Rolls Royce	[illegible]	[illegible]	[illegible]	[illegible]
Dart	Rolls Royce	[illegible]	[illegible]	[illegible]	[illegible]
Eland	Napier	[illegible]	[illegible]	[illegible]	1575
Mamba	Armstrong Siddeley	[illegible]	[illegible]	[illegible]	[illegible]

Type Test November 1949
First Flight May 1949

...mber 1951 TURBO-PROPELLER ENGINE DATA

... CONS. LB F S H P HR	Net Dry Weight (Excluding Prop)	Spec Wt	Type	Remarks
[illegible]	2025	[illegible]	[illegible]	Type Test September 1947 First Flight January 1949
[illegible]	[illegible]	[illegible]	[illegible]	Type Test December 1948 First Flight June 1948
[illegible]	1575	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	Type Test February 1948 First Flight October 1947

[illegible]

We have attempted [illegible] the problems [illegible]

The [illegible] between [illegible] compressors [illegible] practical experience and development [illegible] With [illegible] the early turbo [illegible] between methods (see Table II). A summary of the perfor[illegible] (see Table I) [illegible]

[illegible]

[illegible] Specific weights have been [illegible]

The frontal area of turbojet [illegible] the combustion chambers [illegible] the compressor. [illegible] the use of [illegible] rather than tubular systems [illegible] the [illegible] system and the increase of density [illegible] have helped to reduce the frontal area. Compressor diameters have been kept small by decreasing the [illegible] and departing from the free vortex principle of design. The result today is the achievement of static thrusts of more than half a ton per square foot of frontal area.

Engine	[illegible]
Derwent	[illegible]
Ghost	2[illegible] (1)
G[illegible] 2	4[illegible] (2)
G[illegible] 3	[illegible] (3)
Nene [illegible]	2[illegible]
Nene 1[illegible]	[illegible]
Nene [illegible]	[illegible]

Improvements in component efficiencies have not been very marked in the last few years. It is not difficult to design single compressor and turbine stages of [illegible]% or more in efficiency, but the arrangement of stages in a multistage unit so that efficiency is maintained at the normal design point and operation is satisfactory over a wide range has called for considerable effort of a development nature. That this has been done as pressure ratios have been doubled is a great achievement.

The improvement of fuel economy, other than by improving the aerodynamic efficiency of the components, has involved a balance between considerations of economy, weight and size. With present day efficiencies and temperatures the pressure ratio for optimum fuel economy is well above [illegible] (see Fig. [illegible]) so that provided efficiencies can be maintained, an increase in pressure ratio is profitable. Increasing pressure ratio does eventually reduce the thrust for a given air mass flow, thus leading to a further increase in engine size and weight for a given output. Apart from the tendency of weight to increase with pressure ratio, the designer is faced with the inborn tendency of axial compressors to surge at low speeds. Palliatives such as blow off valves have been frequently used, but each step to higher pressure ratios makes the problem more difficult. Fig. 7 shows in diagrammatic form the characteristics of a theoretical axial compressor. The area of normal operation is bounded by lines showing the stalling and choking of the first and

---

(1) [illegible] Mk. 1 has [illegible] life of [illegible] hours. This will probably be increased to [illegible] hours in the near future. [illegible] Mk. 2 has [illegible] life of [illegible] hours.

(2) This will probably be increased to [illegible] hours. Engines which have run this number of hours are being examined.

(3) This will probably be increased to [illegible] hours. Engines which have run this number of hours are being examined.

[illegible] the shaft [illegible] performance [illegible] a good low speed [illegible] characteristic [illegible] are [illegible] [illegible] therefore. As pressure ratios are increased the [illegible] larger [illegible] the [illegible] performance [illegible] relatively smaller. Above pressure ratios of [illegible] difficulties are [illegible] that the double compressor [illegible] likely to be used.

In the double compressor [illegible] compressor is split into two consecutive units each separately [illegible] turbine. An early example of this general principle is the Rolls-Royce Clyde, as shown in Fig. [illegible] The two compressor units [illegible] axial and the other centrifugal, are mounted in tandem with the shaft of the axial flow pressure compressor running through the [illegible] of the centrifugal (high pressure) compressor and its turbine and [illegible] shaft. Tests with this propeller turbine engine showed that double compounding gives a wider range of surge free operation with rapid acceleration from low speeds. Another advantage of double compression is that, because the two compressors are mechanically independent, it is possible to design each unit for the optimum weight and thereby perhaps effect a reduction of weight as compared to a single compressor [illegible] the design is more of a compromise. Hence, even at pressure ratios of 7 or 8, double compression may make lighter engines possible, especially for large engines. At higher pressure ratios double compressor designs are more attractive than are designs with single rotors. Certainly experience with the Bristol Olympus has [illegible] the [illegible] of the merits of this arrangement.

The first Whittle engine [illegible] for flight at a static thrust of [illegible] pounds. Today engines of about 10,000 pounds thrust are in being and engines of 15,000 to 20,000 pounds thrust are projected. The square-cube law tells us that if geometrical similarity is preserved larger engines will have higher specific weights than small engines. In fact, geometrical similarity is not preserved and jet engines, in common with other structures such as aircraft, have maintained or reduced slightly their specific weight as their size has been increased. Nevertheless it is theoretically and to some extent practically possible to scale down an existing large engine to a smaller size and by taking advantage of the development in mechanical ingenuity and aerodynamic knowledge which has gone into the building of the large engine, to obtain an even smaller

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The Clyde [illegible] turbine drove the low pressure [illegible] propeller [illegible] The low pressure compressor and turbine speeds were [illegible]

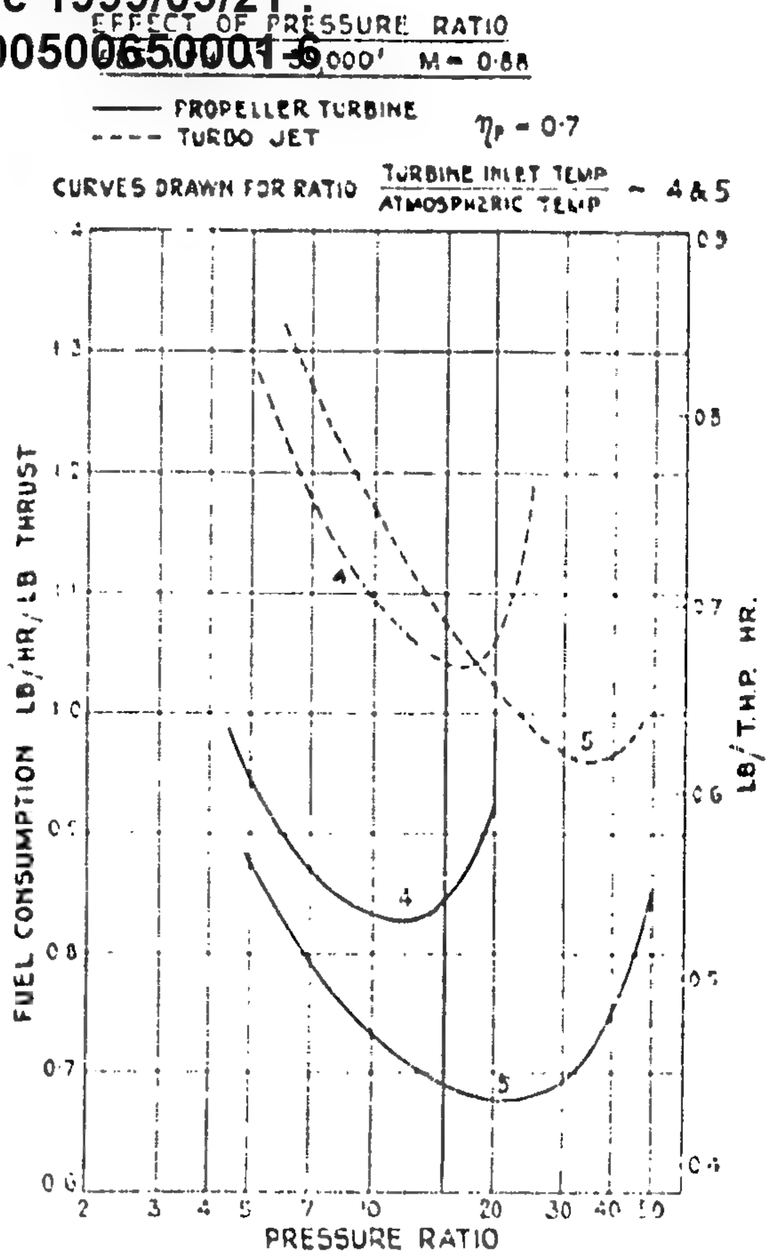

Fig. [illegible] — Effect of Pressure Ratio on Fuel Consumption

[illegible] the [illegible] of engines [illegible]. It is probable however that in this as in other branches of engineering size is a matter of convenience as well as economics, and the complications of having a large number of small units in preference to a few big ones must be taken into account.

Another early notion which has seen much development and is now in practical use is afterburning in the jet pipe to increase thrust. Apart from the advantages for take-off it offers a direct method of giving

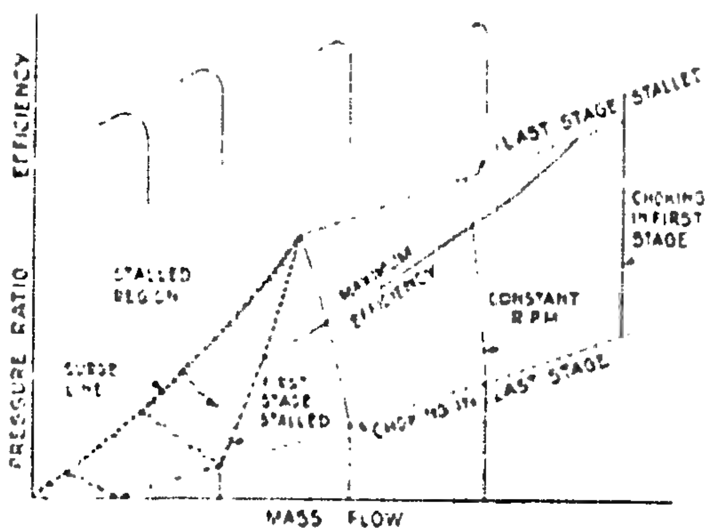

Fig. 7 — [illegible] Characteristics of Typical Axial Compressor

present-day turbo-jet engines enough power to attain supersonic speeds. The development of these afterburning engines and the new jet engines such as the De Havilland Gyron and others in prospect have brought us to the threshold of the next great achievement in aviation, that of sustained supersonic flight.

3.2 *Propeller turbine engines*

Analysis of the performance (and possible uses) of propeller turbine engines showed early that these power plants woulds have important advantages. At speeds below 500 miles per hour they promised a better fuel economy than turbo-jets and a lower specific weight than conventional piston engines. Particularly interesting was the prospect that increasing pressure ratio and temperature would ultimately reduce

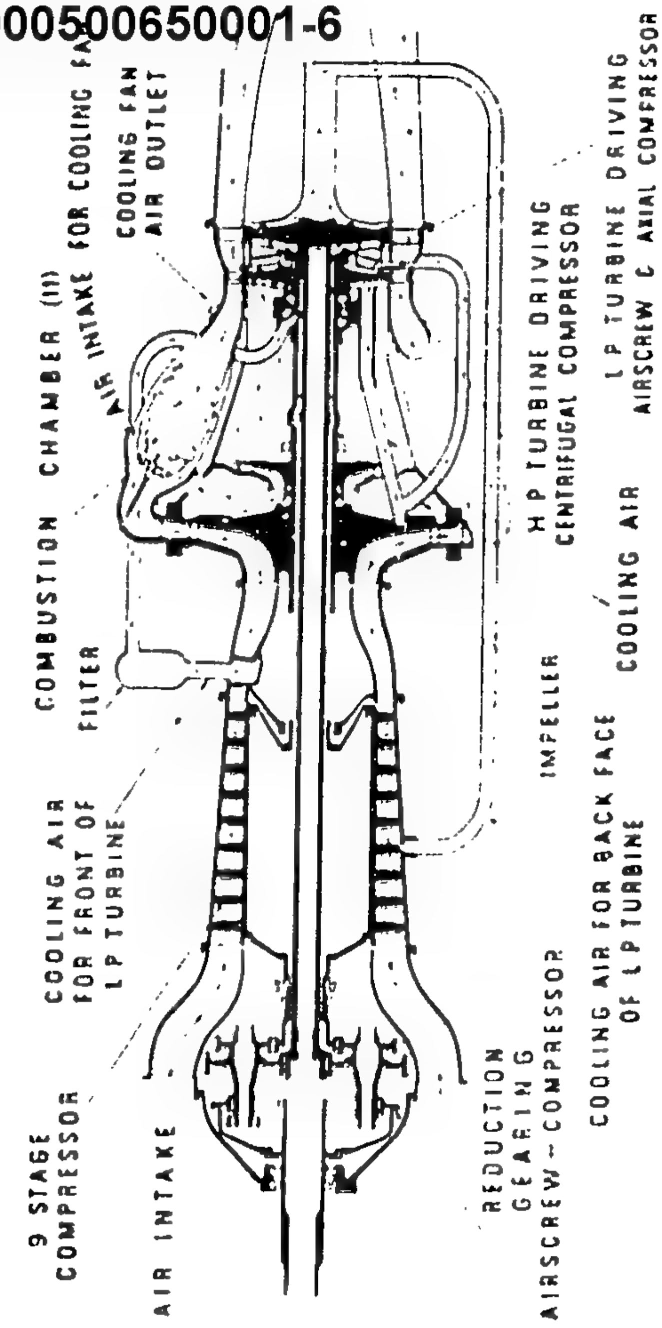

Fig 8 -- Diagrammatic Arrangement of Rolls-Royce Clyde. Double Compound Turbo Prop Engine

[illegible] of a piston engine and so give a power plant [illegible] would be superior in all respects to any we [illegible].

Although the major effort in Britain has been directed toward the development of turbo-jets, a considerable number of propeller turbines have been built. The Bristol Theseus and Armstrong Python demonstrated qualities of performance and reliability which confirmed the early predictions. As already mentioned, the Theseus and Clyde were the first engines to give experience of the mechanical features of twin rotors. When the Armstrong-Siddeley Mamba, Napier Naiad and Rolls-Royce Dart were ordered, the Ministry of Supply not only had specific aircraft requirements to meet, but also had in mind the maintenance of an effort on propeller engines and their problems. Concentration on a few small (1,000 to 2,000 H.P.) engines was judged to give the best return in "know-how" considering the restrictions of a post-war budget and the then state of the art. One reward of this enterprise is the experience now being gained with the Darts in the Viscount.

There has been a greater variety apparent in the turbo-prop engines than in turbo-jets. The arrangements have included single shaft axial compressors (Mamba, Naiad and Eland), reversed compressor layout (Python and Proteus), two stage centrifugal (Dart), combined axial and centrifugal (Proteus and Clyde), separate power turbine (Theseus and Proteus), double compound (Clyde), and a heat exchanger (early Theseus).

This variety has affected the specific weights and fuel consumptions (see Table I). As in turbo-jets pressure ratio is an important factor and the advantages and difficulties of increasing the pressure ratio are somewhat similar. Unlike the turbo-jet, the turbo prop shows an improvement in fuel consumption with increasing temperature, so that turbine blade cooling is likely to have an important application.

The advantage of the gas turbine for large powers was shown early by the Python which gave more power at sea level than any piston engine, although at 50 pounds per second mass flow its swallowing capacity was relatively small. Size however, is limited by propeller capacity and aircraft requirements. Powers of greater than about 5,000 H.P. are not likely to be required for the next few years in British aircraft although some U.S. aircraft may demand propeller power plants of larger size. There is enough experience now to indicate that an engine of this size with high pressure ratio compressors could be developed to have a fuel consumption lower than that of piston engines. Another early prediction about the possibilities of the gas turbine seems about to be fulfilled.

[illegible]

[illegible] the ducted fan engine is intermediate between the jet engine and propeller engine. Compared to the latter, its thrust does not fall off so rapidly with forward speed and propulsive efficiency is not so affected by compressibility. Compared to the jet engine its specific fuel consumption at speeds between 400 and 600 m.p.h. is about 10% less and its ratio of take-off thrust to thrust in flight is greater. Comparisons of ducted fan and jet engines at static conditions, therefore, tend to give a wrong impression, particularly with respect to fuel consumption since the specific fuel consumption of the ducted fan rises more rapidly with forward speed than that of the jet. An important characteristic of the ducted fan engine is that like the turbo-prop and unlike the jet it shows a decrease in fuel consumption with increasing turbine inlet temperature.

In the Power Jets and Metropolitan Vickers ducted fan engines the fan and its turbine were placed behind the engine. In fact, the fan with its turbine was regarded as an augmentor device to be fitted at will

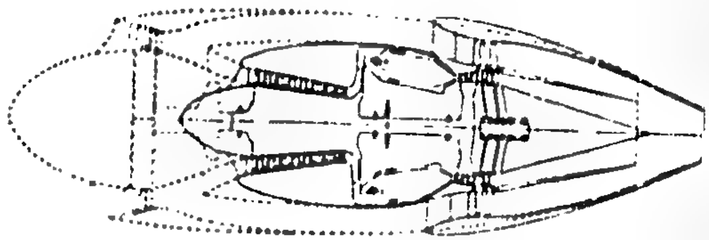

Fig. 9 — Arrangement of Ducted Fan Types of Engine
1 Free Turbine Augmentor (Full Line) or
2 By-Pass Arrangement (Broken Line)

behind an existing jet. It now seems better to include the by-pass feature and place the fan in front so that it can be used to supercharge the main engine. Both these arrangements are shown in Fig. 9. This by-pass ducted fan arrangement is another example in which there is a need for two concentric shafts — single rotors will soon be out of fashion!

The Rolls-Royce Conway will demonstrate the features of the by-pass design and show whether the predicted advantages of this type of engine over the turbo-jet are, as some maintain, merely marginal or whether, as others believe, they are great enough to make the by-pass engine one of the more important developments in aircraft propulsion.

3.4 *Noise*

Although supersonic bangs are the most dramatic noises made by aircraft, the most disturbing are due to the engines. The maximum noise level from a turbo-jet of 10,000 pounds thrust at a distance of 300

feet has reached 125 decibels, and with afterburning it may be as high as 140 decibels. A summary of the work on noise is given by E. J. Richards. Apart from being disturbing sound, sources of such intensity may be dangerous to personnel approaching them. High frequency noise seems to come from the regions of high shear near the edge of the jet and low frequency noise from the large eddies formed further downstream as the jet begins to spread. When the jet is supersonic eddies and turbulence interacting with the shock waves from a resonating system. Subsonically the acoustic power increasses with the eighth power of the jet velocity, in supersonic jets the exponent varies from 14 to 26. Jet velocity is affected by pressure ratio and turbine inlet temperature. A one per cent increase in absolute turbine inlet temperature will increase the acoustic power of a subsonic jet from 4 to 8 per cent. The effect of pressure ratio is shown in Fig. 10.

Work on noise reduction is proceeding. So far it has been found possible to reduce the noise from supersonic jets by fitting teeth-like projections on the inner rim of the jet nozzle which disturb the outer

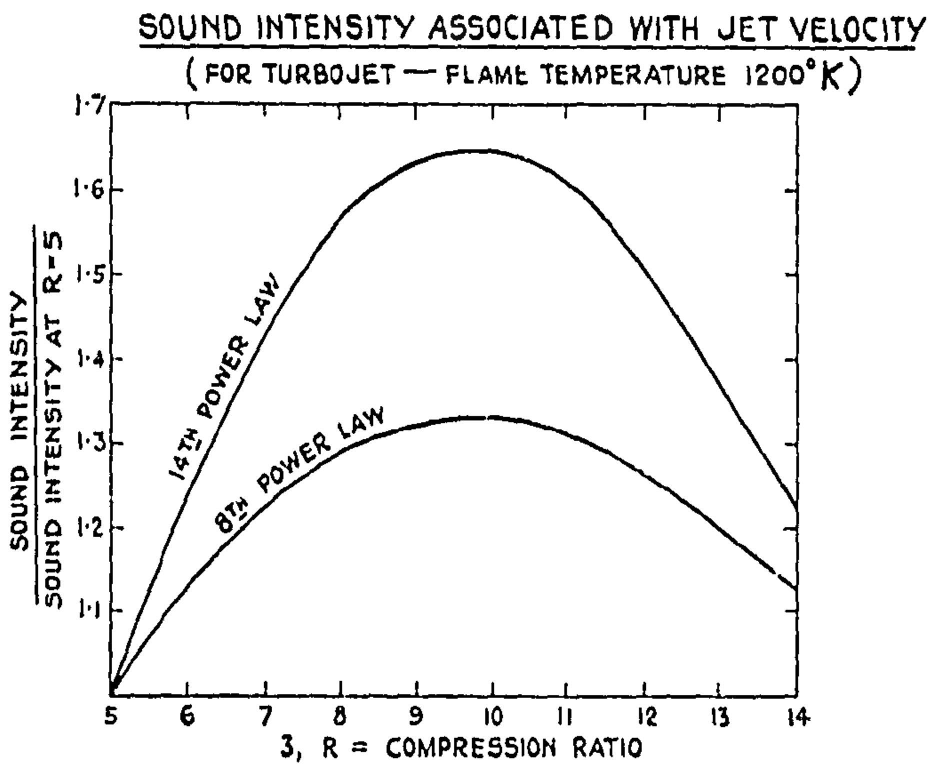

Fig. 10 — The Effect of Turbo Jet Pressure Ratio on Jet Noise

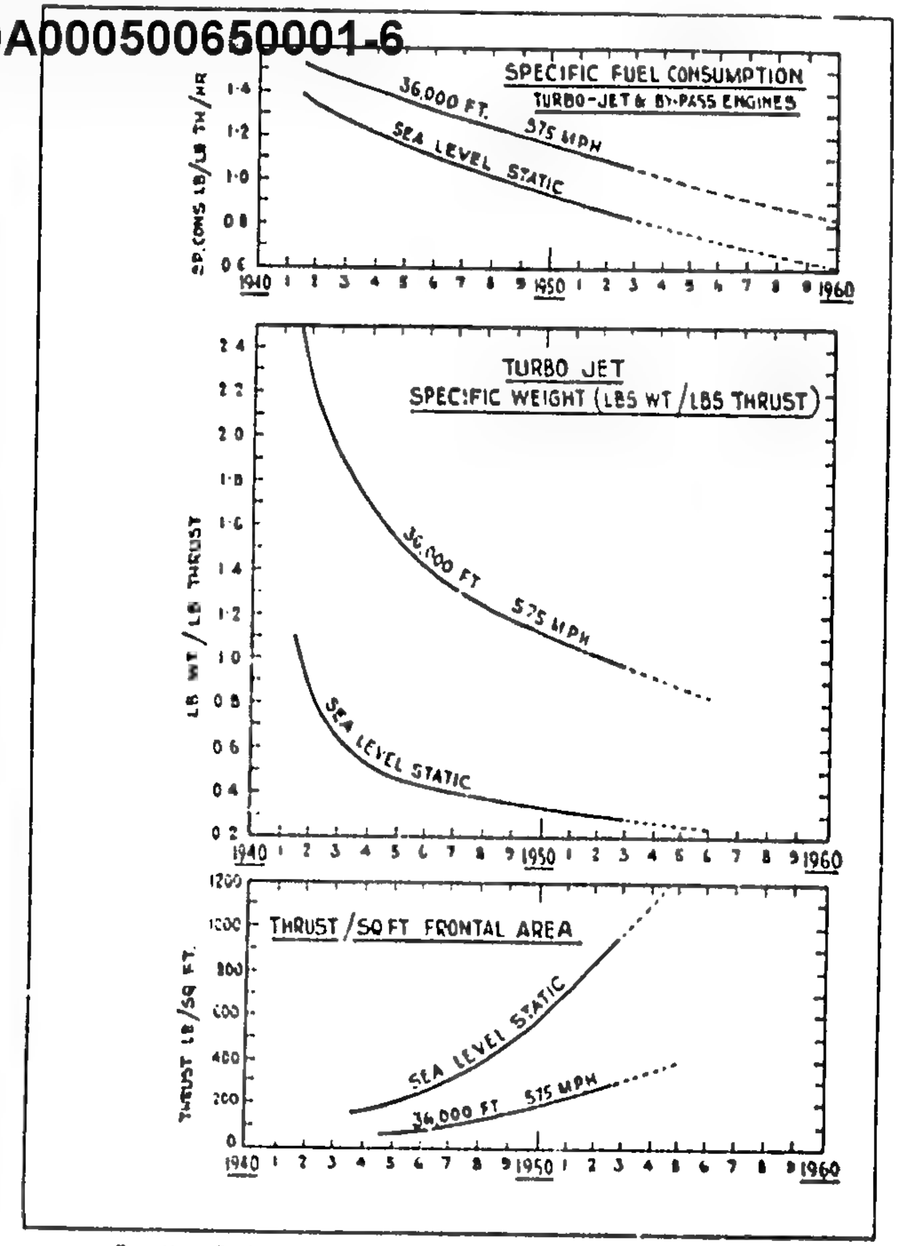

Fig. 11 — Performance of Turbo Jet and By-pass Engines. The Frontal Area Includes Engine and Accessories

edge of the jet stream. Reductions of the noise from subsonic jet is [illegible] perhaps only be satisfactorily achieved by reducing the jet velocity. Low jet velocities are a natural feature of the by-pass engine and it is of great interest that measurements of noise from the Rolls-Royce Conway show that it is appreciably quieter than a comparable turbo-jet.

3.5 *Conclusion*

Some of the achievements of the aircraft engine industry are summarized graphically in Fig. 11. These figures taken from F. R. Banks' address to the Institute of the Aeronautical Sciences in 1953, show the way in which specific fuel consumption, specific weight and thrust per square foot of frontal area of turbo-jets have improved in the last decade. Two curves are shown for each parameter, one relating to sea level static conditions and the other to flight at 36,000 feet and 575 m.p.h. Possible trends are shown by dashed lines. The rapid and steady improvement in the first ten years of gas turbine development is readily seen from Fig. 11. The tendency for the curves to approach a limit may encourage some to draw parallels between this and other new technological advances in which fifteen years of rapid improvement have been followed by only gradual development. In aviation, however, the engine and the aircraft react closely on each other. With supersonic flight banging on the door, new developments in engines will become both necessary and possible. British engine makers may be expected to maintain their steady progress in applying the gas turbine to the new conditions of flight which it has introduced.

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Summary

In this paper the early history of British gas turbines is briefly described and recent developments in Land, Marine and Aircraft Gas Turbines are discussed.

Thirteen separate British firms are engaged in making gas turbines for land use, covering a wide range of sizes from the 50 H. P. Rover "Neptune" engine weighing only 100 lbs. (45.5 kg.) to the 20,000 kW English Electric gas turbo-alternators intended for central power station service. Gas turbines of 900 kW have been standardised by one company and one of these engines supplied power and light at the Engineering, Marine and Welding Exhibition held in London in September, 1953. Another firm has developed a 1,000 kW set which is particularly suitable as a marine auxiliary. Other firms have developed standard units of 2,000 2,500 kW output. In the larger sizes, for outputs of 10,000 kW, 12,500 kW, 15,000 kW and 20,000 kW British manufacturers are showing considerable individuality in their choice of cycles and in general design features.

For traction work two British firms have evolved gas turbine driven locomotives; one of these was delivered to British Railways in 1952. This unit is a gas-turbo-electric drive and uses oil fuel. The second locomotive, at present in course of construction, will be driven by a coal-burning gas turbine.

The gas turbine has also been adapted for road transport, the first gas turbine automobile in the world being a Rover sports model. This gas turbine has many more applications and can be used for boat propulsion, starting units for larger gas turbines, portable generating sets, portable fire pumps, portable air compressors, marine auxiliary purposes and earth moving machinery.

Many marine engine builders are developing gas turbine units and their research activities are pooled in the formation of The Parsons and Marine Engineering Turbine Research and Development Association at Wallsend on Tyne. In addition, a number of other land gas turbine builders have turned their attention to marine propulsion by gas turbines. The first gas turbine propelled ship in the world was the Motor Gun Boat No. 2009 of the Royal Navy which put to sea in July 1947. This was followed by the tanker "Auris" the first merchant vessel to have a gas turbine as one of her main engines. A smaller type of marine gas turbine has been developed for harbour launches and similar duty. The highest powered marine gas turbine under development anywhere in the world is a 6,000 s.h.p. unit of lightweight construction specially designed to retain its high efficiency at low powers. Two of these engines are shortly to be installed in place of the original propelling machinery in H. M. S. "Grey Goose".

Much intensive work is being undertaken by industrial concerns and others to solve the problems arising from the deposition of ash from residual oil fuels on turbine components working at high temperatures, and this work is already bearing fruit. Sponsored by the Ministry of Fuel and Power investigations are also being made into the problems associated with the burning of solid fuels such as coal and peat.

In the aircraft field, the paper reviews the progress made in jet propulsion gas turbines, propeller gas turbines, and ducted fan gas turbines, and details are given of the performance and history of many of the British engines of these different kinds. The developments of the last few years in compressor design, fuel economy and specific weight are discussed, bridging the gap between the 850 lb. thrust of the first Whittle jet propulsion engine to fly and the 10,000 lb thrust engines in being. Engines of 15,000 to 20,000 lb. thrust are projected.

Recent progress in ducted fan engines, exemplified in the Conway "by-pass" design, is of special interest in that it may result in power plants appreciably less noisy than the comparable jet propulsion engines.

Supersonic flight will demand new development in engines and the British engine makers can be expected to maintain steady progress in further developing the gas turbine in the new conditions of flight which it has introduced.

SUMÁRIO

[illegible] brevemente os primeiros tempos da história das turbinas a gás britânicas e examina os progressos recentes em turbinas a gás para uso terrestre, marítimo e aeronáutico.

Treze firmas britânicas independentes estão empenhadas no fabrico de turbinas a gás para uso terrestre, abrangendo grande número de tamanhos desde o motor Rover "NEPTUNE" de 50 cavalos, pesando sómente 100 libras (45 Kilos e 500 gramas), aos tubos-alternadores a gás de 20.000 kW da ENGLISH ELECTRIC, destinados a serviço em centrais elétricas. Uma companhia padronizou turbinas a gás de 900 kW e um dêsses motores forneceu energia e luz à exposição "ENGINEERING, MARINE & WELDING EXHIBITION" realizada em Londres em setembro de 1953. Uma outra companhia produziu um grupo de 1.000 kW que é particularmente apropriado para serviço auxiliar marítimo. Outras firmas fabricaram unidades padrão capazes de fornecer 2.000 · 2.500 kW. Em tamanhos maiores, para potências úteis de 10.000 kW, 12.500 kW, 15.000 kW e 20.000 kW os fabricantes britânicos mostram considerável individualidade na escolha dos ciclos e características gerais do projeto.

Para trabalho de tração duas firmas britânicas produziram locomotivas acionadas por turbinas; uma destas locomotivas foi entregue à "BRITISH RAILWAYS" em 1952. Esta unidade turbo-elétrica a gás utiliza óleo combustível. A segunda locomotiva presentemente em construção será acionada por uma turbina a gás queimando carvão.

A turbina a gás também foi adaptada a veículos de estrada, sendo um carro esporte ROVER o primeiro automóvel do mundo com uma turbina a gás. Esta turbina a gás tem muitas outras aplicações, como sejam: propulsão de barcos, unidade de arranque para turbinas a gás maiores, grupos geradores portáteis, bombas de incêndio portáteis, compressores portáteis de ar, serviços auxiliares marítimos e maquinária para remoção de terra.

Muitos construtores de motores marítimos estão em vias de produzir turbinas a gás e seus trabalhos de investigação encontram-se combinados numa associação denominada "THE PARSONS & MARINE ENGINEERING TURBINE RESEARCH & DEVELOPMENT ASSOCIATION" em WALLSEND ON TYNE.

Além dêstes, um certo numero de fabricantes de turbinas a gás terrestres voltaram sua atenção à propulsão marítima por turbina a gás. O primeiro navio do mundo movido por uma turbina a gás foi a canhoneira motor n.º 2009 da Marinha Real Britânica, que foi lançada ao mar em julho de 1947. Seguiu-se o petroleiro "AVRIS", o primeiro navio mercante a utilizar uma turbina a gás como um de seus motores principais. Um modêlo menor de turbina a gás marítima tem sido aperfeiçoado para lanchas de pôrto e serviços semelhantes.

A mais potente turbina marítima a gás em construção no mundo é uma unidade de 6.000 cavalos efetivos, de estrutura ligeira especialmente calculada para manter seu alto rendimento a pequenas cargas. Duas destas turbinas deverão em breve substituir a maquinária de propulsão original do H.M.S. "GREY GOOSE".

Emprêsas industriais e outras entidades têm trabalhado intensivamente e com algum sucesso na solução de problemas originados pela deposição de cinzas de óleos combustíveis residuais nos componentes da turbina submetidos a altas temperaturas.

Sob o patrocínio do "MINISTRY OF FUEL & POWER" investigam-se também os problemas associados ao emprêgo de combustíveis sólidos tais como o carvão e a turfa.

No campo da aeronáutica, o relatório refere-se ao progresso feito em turbinas para propulsão de jato (turbo-jatos), turbinas para propulsão de hélices (turbo-propulsores) e turbinas de "ducted fan" e dá detalhes das características e história de muitos motores britânicos dêstes vários modelos. Examinam-se os progressos feitos em problemas relacionados com compressores, economia de combustível e pêso específico durante os últimos anos abrangendo o período decorrido entre as 850 libras de impulso do primeiro motor a jato WITTLE a voar e as 10.000 libras de impulso dos motores atuais. Planejam-se motores de 15.000 a 20.000 libras de impulso.

O progresso recente em motores de "ducted fan", exemplificado no modêlo "by-pass" CONWAY, é de interêsse especial porque poderá resultar em motores apreciàvelmente menos ruidosos que os equivalentes motores a jato.

O vôo supersônico requererá novos aperfeiçoamentos em motores e é de crer que os fabricantes britânicos mantenham um progresso constante no melhoramento da turbina a gás tendo em vista as novas condições de vôo por ela introduzidas.

Résumé

Ce rapport décrit brièvement l'histoire primitive des turbines à gaz britanniques et discute les développements nouveaux qui concernent les turbines à gaz terrestres, marines et aéronautiques.

En Grande Bretagne treize constructeurs différents s'occupent de la fabrication de turbines à gaz destinées à l'utilisation industrielle; celles-ci couvrent une gamme étendue de puissances, du moteur Rover "Neptune" de 50 ch. dont le poids ne dépasse pas 45.5 kg. aux turbo-alternateurs de 20,000 kW, fabriqués par la Compagnie "English Electric" et destinés au service dans une centrale thermique. Des turbines à gaz d'une puissance de 900 kW ont été normalisées par un certain fabricant et un de ces moteurs a récemment fourni l'énergie et l'éclairage à l'expo-

[illegible] Engineering [illegible] and Welding" qui a eu lieu à Londres au mois de septembre 1952. Un autre fabricant a développé une installation de [illegible] kW qui se prête particulièrement bien aux services auxiliaires de bord. D'autres constructeurs ont développé des installations normalisées de 2,000/2,500 kW. Dans leurs machines plus grandes, pour des puissances de 10,000 kW, 12,500 kW, 15,000 kW et 20,000 kW, les constructeurs britanniques démontrent une individualité importante en ce qui concerne leur choix de cycles et les détails du dessin en général.

Pour la traction ferroviaire, deux constructeurs britanniques développent des locomotives propulsées par les turbines à gaz; une de ces locomotives fut livrée aux "British Railways" en 1952. Cette installation comporte une turbine à gaz, qui emploie le mazout comme combustible et la transmission électrique. La deuxième locomotive, actuellement en construction, sera commandé par une turbine à gaz ayant comme combustible le charbon.

La turbine à gaz a été aussi adaptée au transport par route; la premier auto du monde propulsé par une turbine à gaz est une voiture sport "Rover". Le moteur construit surtout pour l'auto a un champ d'application bien plus étendu, par exemple, pour la propulsion de bateaux, pour le démarrage de turbines à gaz plus grandes, pour les groupes électrogènes mobiles, pour les pompes à incendie mobiles, pour les compresseurs d'air mobiles, pour les machines auxiliaires de bord et pour les machines à déblayer.

Plusieurs constructeurs de moteurs marins sont en train de développer des installations à turbine à gaz et leurs services d'études et de développement, sont réunis dans une association, sous le titre, "The Parsons and Marine Engineering Turbine Research and Development Association", à Wallsend-on-Tyne. En plus, certains autres constructeurs de turbines à gaz terrestres se sont occupés de la propulsion marine au moyen de turbines à gaz. Le premier navire du monde propulsé par une turbine à gaz fut la canonnière à moteur, no. 2009, du "Royal Navy", qui a pris la mer en juillet 1947. Elle a été suivie par le pétrolier "Auris", qui fut donc le premier navire de la marine marchande à employer une turbine à gaz comme une de ses machines principales. Un modèle plus petit de turbine à gaz marine a été perfectionné pour les vedettes de port et pour de pareils emplois. La turbine à gaz marine de la plus grande puissance du monde, qu'on développe actuellement, est un appareil de construction légère, dessiné spécialement de façon à maintenir son rendement élevé aux basses charges. On installera bientôt deux de ces moteurs dans le "H.M.S. Grey Goose", qui remplaceront les machines originales de propulsion.

Des firmes industrielles et d'autres organisations et personnes entreprennent à présent des travaux intensifs, afin de résoudre les problèmes occasionnés par le dépôt de cendres des mazouts sur les pièces qui

subissent une température élevée pendant le fonctionnement de la machine et ces travaux donnent déjà de bons résultats. Patronné par le "Ministry of Fuel and Power" à Londres, on fait également des recherches dans les problèmes apportés par l'emploi de combustibles solides, tels que la houille et la tourbe.

Dans le domaine de l'aviation, ce rapport donne un compte rendu du progrès fait dans les turbo-réacteurs, les turbo-propulseurs et les turbo-réacteurs à deux fleuves, et présente des informations détaillées au sujet du rendement et de l'histoire de plusieurs moteurs britanniques de ces différentes espèces. On considère les progrès qu'on a faits pendant ces dernières années en ce qui concerne le dessin des compresseurs, l'économie en combustible et le poids spécifique, passant ainsi de la poussée de 386 kg du premier moteur à réaction Whittle, qui a volé, à la poussée de 4.500 kg des moteurs actuels. La construction des moteurs qui donneront une poussée de 6.800 kg jusqu'à 9.000 kg est projetée.

Le progrès récent dans les turbo-réacteurs à deux fleuves, dont le modèle "by-pass" Conway offre un des meilleurs exemples, est d'une importance spéciale, du fait qu'il peut en résulter des appareils de production d'énergie faisant appréciablement moins de bruit que les moteurs à réaction comparables.

Le vol supersonique exigera de nouveaux développements dans les moteurs et on peut s'attendre à ce que les constructeurs britanniques continueront de faire des progrès constants dans le développement futur de la turbine à gaz, dans les nouvelles conditions d'aviation ainsi introduites.

CONFERÊNCIA MUNDIAL DA ENERGIA
WORLD POWER CONFERENCE

Titulo 2
Assunto 2 1 1

REUNIÃO PARCIAL
SECTIONAL MEETING
Rio de Janeiro - 1954

SEXTON (J. K.)
Canada

THE INFLUENCE OF TROPICAL AND SUB-TROPICAL FACTORS IN THE DESIGN OF HYDRO-ELECTRIC PLANTS

By J. K. SEXTON

CANADIAN NATIONAL COMMITTEE

INTRODUCTION

The power resources of a river depend on the flow of water that can be made available and the head that it is feasible to develop in one or more power sites. The rate of flow depends not only on the annual volume of runoff and the natural distribution of that runoff over the seasons of the year but also on the reservoir sites that can be developed to store water during periods of high flow and discharge it during periods of low flow. Head can be concentrated by constructing a dam across the river where the cross section and foundation conditions are favourable, or it can be obtained by a canal, tunnel or penstock to bypass the water around a fall or rapid reach of the river. Frequently a combination of these two methods is used, and sometimes it is possible to develop great concentrations of head by diverting one drainage basin into another. The power plants so constructed must be able to contend with all the forces of nature that may be thrown out of balance by the artificial obstruction and diversion of streamflow: big floods must pass safely over the dams; ice must not endanger the structures or block the water passages; gravel and silt must not be allowed to fill reservoirs and canals. If these problems can be solved with structures sufficiently low in cost to permit generation of electrical energy at a price that is cheaper than that of energy produced by thermal plants, then the water power resources in question constitute a valuable national asset.

The problems vary in the different temperature zones of the earth's surface and hydro-electric practices must conform to the requirements of the region if maximum value from water power resources is to be obtained.

PECULIAR FEATURES OF TROPICAL AND SUB TROPICAL REGIONS AFFECTING THE DESIGN OF HYDRO ELECTRIC PLANTS

Meteorological

Temperature is the fundamental variable between the tropical regions and those further from the equator. At sea level a mean annual temperature of approximately 27° C prevails over a belt 30° wide at the equator and diminishes with north and south latitude in a variable manner depending on ocean currents and prevailing winds. Mean monthly freezing temperatures at sea level are first encountered at about latitude 38° in the northern hemisphere and mean annual freezing temperatures at about latitude 50°. Temperatures also decrease with altitude so that some localities in tropical latitudes have temperate climates. La Paz in Bolivia, for example, at an elevation of 3658 meters and a latitude of 16° 30' S has a mean annual temperature of 9.5° C which is but slightly higher than that of Santa Cruz at sea level in Argentina at a latitude of 50° 11' S.

As a direct consequence of the higher temperatures of the tropics the rate of evaporation is also high and relative humidity tends to vary between an extreme high in the wet season and an extreme low in the dry. Evaporation of over two meters per year is common near the equator, whereas the maximum rate in a climate such as that of Canada seldom exceeds one meter per year.

The peculiar winds of the tropical and sub-tropical regions exert both a direct and indirect influence on the design of hydro-electric plants. Most obvious of these are the hurricanes of the Caribbean Area and the typhoons of the south west Pacific that bring destructive wind velocities and torrential rains. Of indirect importance are the periodic winds of the tropics that make a reversal of direction between winter and summer and thereby accentuate the tendency to divide the year into two radically different seasons, the rainy and the dry. The best example of these are the monsoons of the Indian Ocean that carry heavy rains in a north easterly direction towards the Asiatic mainland during the summer months and are reversed in winter time to create a period of drought.

Geographical

There has been no recent glaciation on a large scale in the tropics such as occurred in North America where the ice cover extended as far south as latitude 38° N at Cincinnati or in Europe where it reached a latitude of 52° N. Recent glaciation has occurred at a few limited areas of high altitude in the tropics such as in the highlands of the Andes and the Himalayas but the total effect has been small. As a result, tropical river basins do not usually contain the many lakes and irregularities

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found on water courses farther north which provide natural regulation [illegible] and facilitate creation of artificial storages. There are, of course, some notable exceptions such as the great lakes of Central Africa which contribute to the enormous water power resources of that continent, but as a general rule there is a scarcity of lakes and ponds in tropical and sub-tropical regions which makes the regulating of runoff difficult.

Hydrological

Since the principal source of precipitation is water previously evaporated from land and water surfaces, it follows from the high evaporation rate of the tropics that there is generally a greater volume of rainfall in tropical latitudes than in other parts of the world. This rainfall is by no means evenly distributed and the location of mountain ranges in relation to prevailing winds causes areas of permanent drought in the tropics just as it does in other areas further from the equator. The coastal plain of Peru is an excellent example of such drought. Where geographical features do not prevent precipitation, however, the general tendency for greater rainfall in the tropics prevails. An examination of the map of mean annual precipitation given in Fig. 1 will serve to illustrate this point.

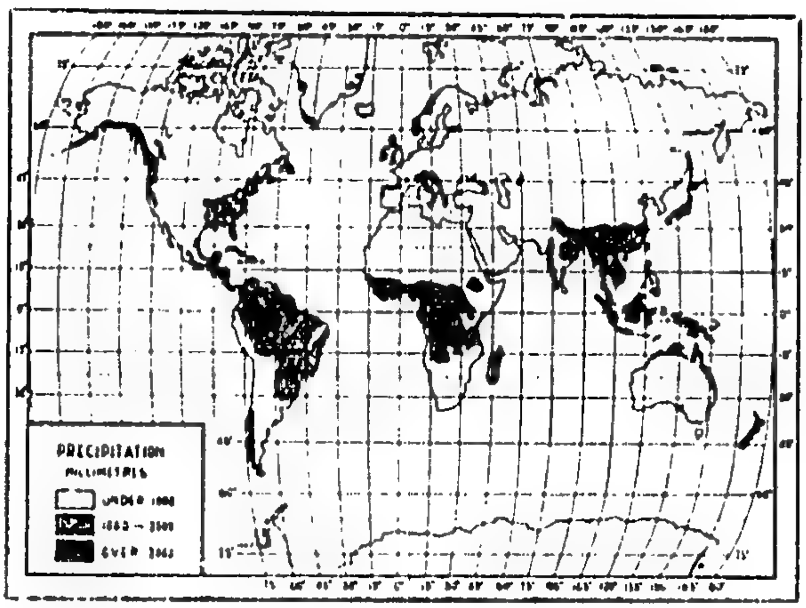

Fig. 1 — World map of mean annual precipitation

The greatest intensities of rainfall are also found in tropical and [illegible] as is evidenced from the following approximate tabulation of maximum recorded rainfalls of the world.

Duration	*Rainfall in meters*	*Location*		*Latitude*
1 year	23 meters	Cherrapunji, India	1860	25°16'N
1 month	9 "	" "	1861	"
5 days	3.8 "	" "	1841	"
4 "	2.1 "	Funkiko Taiwan,	1913	23°·N
2 "	1.6 "	Cherrapunji, India,	1876	25°16'N
1 day	1.1 "	Baguio, P. I.	1911	16°30'N

The net hydrological effect of the various climatic and geographic factors acting on tropical regions — high temperatures, periodic winds, high evaporation rates, scarcity of lakes, high rates of rainfall — is to produce a large volume of runoff with great seasonal variation and high rates of flood discharge. A tropical river derives most of its flow from ground water during the dry season months, and runoff during this season is low and uniform with a tendency to slight diminution as the season progresses. It may even disappear entirely, as happens to many of the streams of South Africa. With the arrival of the rainy season, however, the flow rises immediately to a series of irregular peaks which follow the variations of rainfall over the drainage basin. The pattern of peaks is difficult to predict and the flow may rise to great heights with little warning. Fig. 2 shows a hydrograph of the Lempa River in El Salvador for 1945 and is typical of tropical rivers in climates with distinct wet and dry seasons. It will be noted that during the early part of the rainy season the flow returns almost to its preceding dry season low after each freshet.

Excepting the Nile River with its record of gauge heights going back to 640 A. D., the records of stream flows of tropical and subtropical rivers are not usually as extensive as those of more northerly rivers. Accordingly, a statistical analysis of the measurements available may fail to disclose the heights to which maximum floods in the tropics can rise and there is a temptation to apply flood constants determined for more northerly rivers. Caution is advisable in this case if structures that will not stand overtopping are involved. Referring to Creager's equation for flood flow, a value of C of 30 or less may be adequate in the latitudes of Canada but values greater than 100 may be required in the tropics.

In certain tropical regions the phenomenon of hurricanes and typhoons is a serious factor contributing to floods. During the past 26 years at least two hurricanes have caused floods in the Caribbean area

[illegible]-electric installations. In 1928 a hurricane [illegible] caused floods of unprecedented magnitude [illegible] on the La Plata River. Plate 1 shows all that was left of one of these plants after the flood had passed. Again in June, 1934 another Caribbean hurricane crossed to the Pacific Coast of Central America and caused floods in El Salvador that completely submerged most hydro-electric installations in the country. At the Rio Sucio Plant on the river of the same name with a drainage area of 440 square kilometers the maximum flow was calculated to be 3600 c.m. sec., and on the Lempa River with a drainage area of 17,254 square kilometers the maximum flow was estimated at 25,000 c.m. sec.

Miscellaneous

The main feature to be mentioned under this heading is the almost invariable tendency of tropical rivers to carry heavy silt loads during the flood season. The problems of soil erosion and sedimentation are by no means confined to the tropics. Heavy loads of sediment may be encountered in the glacial streams of northern British Columbia as well as in rivers near the equator, and probably the highest silt rates in the world are found in the Yellow River in China and the Little Colorado in the United States — both in temperate regions. However, these are exceptional cases. Most of the major power rivers of the higher latitudes give little trouble from silt. In tropical and sub-tropical regions, on the other hand, the intense rains and rapid runoffs alternating with seasons of drought add a high silt content to most rivers, particularly to those of steep gradient on which power sites are usually found.

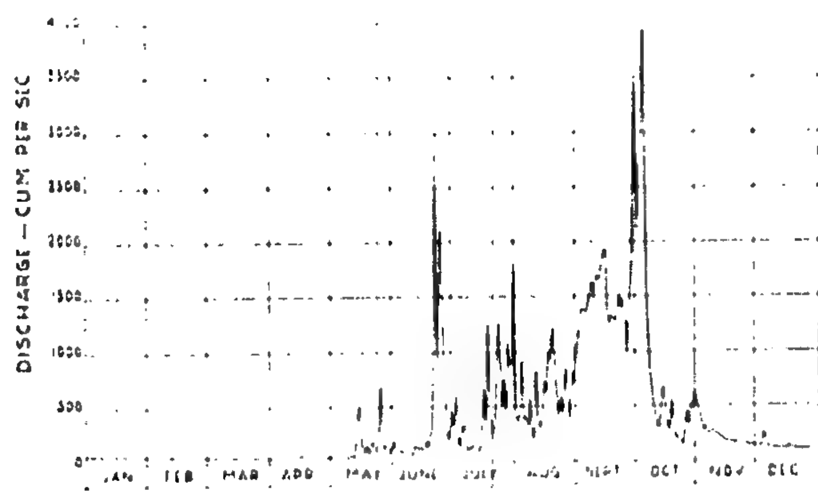

Fig. 2 — Hydrograph of the Lempa River in El Salvador for 1945

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[illegible] FEATURES ON HYDROELECTRIC PLANNING AND DESIGN

General

It is seldom possible to develop a tropical river entirely for hydro-electric production. Usually the water must be shared with irrigation and where there is conflict of interests those of irrigation predominate. Unlike the higher latitudes where frosts restrict the growing season, it is possible in the tropics with irrigation to extend the growing season over the entire year, and thereby enhance the productivity of land enormously. This, for example, is the situation in India where irrigation comes first, power second, and flood control third.

The ideal arrangement exists when both reservoir and power sites are found upstream from the large irrigable areas, such as occurs on the Nile. In this case it is possible to generate a maximum of primary energy. When the power reaches of a river lie below the irrigable areas or are found in the drops of the irrigation canals the quantity of water available for power is reduced and the supply may be variable. In such cases much of the hydro-electric energy is secondary and must have the backing of thermal generating stations. This has happened in a number of cases in India. On the big Damodar River scheme, for example, the base load is carried by hydro for only 15 weeks of the year and by steam for the remainder of the time. Hence in appraising the overall development of a river in a tropical or sub-tropical region it is usually necessary to consider the effect of present and future irrigation, and if the water is to be shared with irrigation then costs should also be shared. While the cost attributable to hydro may be thus reduced, utility for generation of primary energy is also impaired and duplication of generating capacity in thermal stations may eventually be required.

The sharing of costs between hydro and irrigation, however, is usually confined to multiple purpose structures on large scale river developments, and these have been relatively few in the tropics. Most developments to date have consisted of small plants devoted entirely to hydro and operating under such restrictions as irrigation requirements may impose. The importance of the small hydro plant in the tropics is well illustrated by the case of Brazil which is usually thought of as a country of large scale hydro-electric development owing to the prominence of the big power plants diverting the headwaters of the Parana River to the Brazilian Atlantic Coast. As a matter of fact, in the 1948-50 Statistical Year Book of the World Power Conference Brazil reported a total of 1091 hydro plants with an average installation of 1400 KW per plant — a lower average plant capacity than reported by any nation except Greece. It is probable that such small plants will continue to play an important role in tropical economy.

[illegible] recent development that [illegible] [illegible] introduction of automatic and remote controlled operation. The equipment involved has two functions: first to protect the installation against mechanical or electrical failure of the most vulnerable parts, and second to control plant operation. The protection consists of relays to give alarm and close down the units in event of trouble, while the control is open to several alternatives. Control can be transmitted from a remote center, it can be automatic, or it can be a combination of both types. Remote control is normally used for a power system depending primarily on hydro. An excellent example is found in a small plant recently constructed on the Umtata River in Cape Province, South Africa, and controlled by push button from an office at the load center in the town of Umtata 4 miles distant. On the other hand, automatic operation is well suited for small hydro plants operated in conjunction with thermal plants, particularly if the ratio of hydro to steam capacity is small. For example, a 250 KW plant on the Guariquito River in Venezuela is interconnected with a 12,000 KW diesel generating station in Barquisimeto and equipped with float-controlled automatic operation which keeps the turbine gates full open during periods of excess flow and adjusts gate position to use all the water available during dry periods.

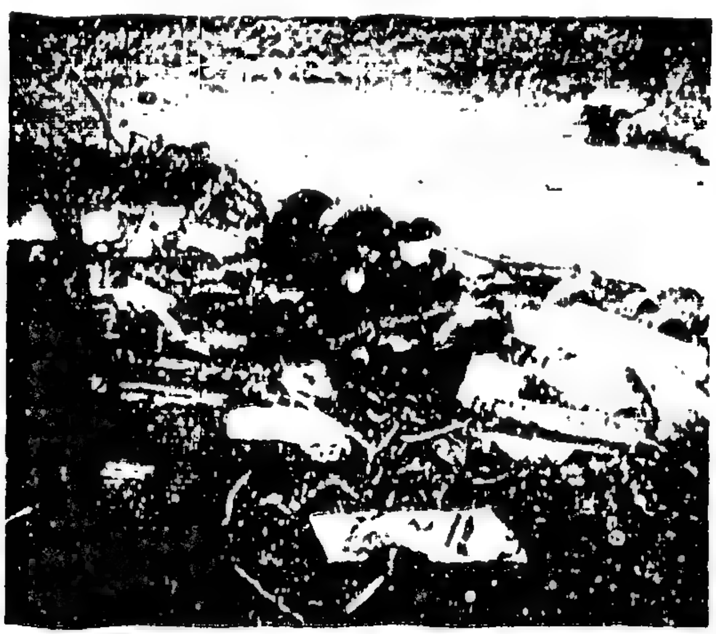

Plate [illegible] — All that remained of [illegible] Plant [illegible] on the La Plata River in Puerto Rico after the [illegible] hurricane

An advantage which all tropical power plants both large and small enjoy over plants in higher latitudes is the complete freedom from ice. In many cases this advantage is at least partially offset by the substitution of silt and high flood troubles but none-the-less it permits greater flexibility in layout of hydro structures than is possible in a northern region such as Canada. For example, in the tropics there is no particular difficulty in diverting water for hydro purposes from a swift stream by means of a low dam, providing that the diversion structure is designed to avoid the intake of silt. Such is not the case in colder climates where continuous diversion from a swift stream can only be effected if storage volume is provided to hold back the slush ice in winter. Nor is there any particular difficulty with the use of high velocity flumes and canals in the tropics, whereas they may be out of the question in low temperature regions. These advantages account in part for the popularity of small hydro-electric plants in tropical and sub-tropical regions.

Reservoirs

The problems of silting and evaporation are usually much more serious in the design of tropical reservoirs than in the design of reservoirs for temperate climates.

Theoretically, all reservoirs tend to decrease in volume through sedimentation and ultimately to disappear from use. In regions not seriously effected by soil erosion, however, the process is so slow that it has little or no effect on hydro-electric design. This is not the case in the tropics and only when storage is created on a natural lake such as Lake Victoria in Africa is it safe to ignore the silting problem. Usually it is necessary to take such measures as are available to extend reservoir life to an acceptable period, say not less than 100 years. Fortunately the creation of Lake Mead in the United States focussed attention on the problem and subsequent studies have lead to a better understanding of these corrective measures. The more important ones are summarized as follows:

1. The volume of a storage reservoir should be sufficiently large in relation to upstream drainage area to extend reservoir life to the required length of time. Preferably the volume should be such as to result in a reduction through silting of less than one half of one per cent per annum.

2. If surplus water is available it may be possible to pass 10% or more of the incoming sediment through a reservoir by venting of density currents through low outlets at the dam. The muddy water entering a reservoir drops its bed load and the

heavier [illegible] particles [illegible] the reservoir but the finer particles are carried [illegible] current of greater density which follows the bottom of the reservoir downstream to the dam.

3. Pondage reservoirs can be restored to at least partial capacity and their life prolonged indefinitely if they are drained and flushed periodically through cleanout sluices of adequate capacity near the bottom of the dam. All low dams on silt carrying rivers in the tropics should have this provision.

4. In the case of small pondage reservoirs it is possible to keep the bed load and much of the heavier sediment of the stream from entering by constructing a bypass canal around the reservoir. The canal and the pond are connected by a submerged weir and in the canal downstream from this weir there is a control structure which is used to discharge flood water during the rainy season or to flush out the accumulated sediment from in front of the submerged weir at intervals during the dry season. Fig. 3 shows a pondage reservoir with bypass canal constructed for the Cuticucho Plant on the Zongo River in Bolivia.

Evaporation also has a serious effect on tropical reservoirs and tends to lower their efficiency, i.e. the ratio of discharge to inflow volumes. In tropical regions the average rate of evaporation from lake surface may vary between 0.06 and 0.10 cu m sec per square kilometer. Thus when a lake is raised and its area increased for storage purposes the gain in regulated flow will be at least partially offset by increased evaporation losses. As a matter of fact it has been calculated in the case of Lake Kivu in the Belgian Congo that potential power output could be increased by tapping the lake with a deep tunnel and lowering the range of regulation level thereby reducing surface area and evaporation losses so as to more than offset the loss of head. This feature must be kept in mind when increasing reservoir volumes either for streamflow regulation or silt retention.

The evaporation from water surfaces downstream from reservoirs must also be taken into account when planning the development of a tropical river. An extreme example of this occurs on the Nile which receives the greater part of its supply from the White Nile rising in the Lake Victoria region. The White Nile loses 14,500,000,000 cu m of water annually or 55% of its total flow in the swamps of the Sudd region between Mongalla and Malakal. In the meantime Egypt and the Sudan are short of water in dry years — a situation that could only be corrected by some form of canalization through the Sudd.

The design of dams in tropical and sub-tropical regions is usually featured by the high flood discharge capacity that must be provided and it is not uncommon to find both high level crest gates and low level sluices required. The absence of freezing temperatures makes for greater freedom in selection of flood discharge equipment, and advantage is occasionally taken of this fact to install automatic regulating gates of types that would not be practical in northern climates. For the most part, however, the taintor gate and the wheeled gate are most commonly used for discharge control.

Special care must be taken to provide adequate flood discharge capacity if earth fill dams are used in the tropics. On the other hand, an earth fill side dam of small size compared to the main structure can be used as an emergency relief or "fuse plug" designed to fail by overtopping in the event of a super flood. Such an earth fill "fuse plug" has been constructed at the Guayabo Dam in El Salvador. The drying

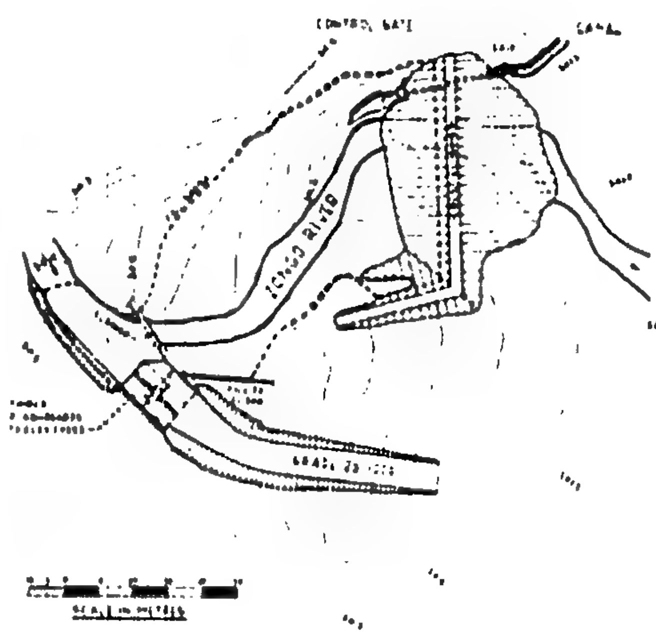

Fig. 3 — Cuticucho dam and bypass canal on the Zongo River in Bolivia

and cracking of earth dams during periods of storage drawdown may [illegible] dry season of low relative humidity. This difficulty has been reported from India and Indonesia.

The freedom from freezing temperatures allows a wider choice of concrete structures in the tropics. Disintegration of concrete surfaces at the water line is more or less eliminated and the spalling of exposed downstream surfaces due to seepage is greatly reduced. These circumstances favour the use of the hollow buttress dam constructed with reinforced concrete. The fact that this type of dam has not had wider acceptance in the tropics is probably due to the high cost of formwork, reinforcement, and high strength concrete as compared with stone masonry and cyclopean concrete.

Another feature in the design of concrete (or masonry) dams in the tropics is the absence of thrust from an ice sheet on the reservoir. This may amount to 15 metric tons per linear meter of dam in cold climates. On the other hand, the design of tropical dams should frequently make allowance for the thrust of submerged silt deposits against the upstream face in addition to water pressure.

Intake structures

Intake works in the tropics can frequently be of somewhat simpler design than in higher latitudes. No ice chutes or protective curtain walls in front of screens are required. Moreover, it is possible to use unprotected intake towers standing in the reservoir upstream from the dam, a type of construction seldom feasible where an ice sheet exists.

Intakes from low head diversion works in the tropics, however, must usually be designed to protect against entry of silt, and experience has led to the adoption of a more or less standard layout of structures.

1. Water is drawn into the intake normal to the direction of the stream. To accomplish this the intake is located in the bank upstream from one end of the dam and as near to it as possible.

2. Sluice gates are located in the dam next to the intake, and the sills are set near river bed level.

3. The sill of the intake should be elevated several feet above the sluice gate sills.

During periods of excess water the sluice gates adjacent to the intake are kept open to keep the bed load moving past the front of the intake and retain the main channel of the stream at that side of the river. During periods of low water the sluice gate nearest the intake

is either kept open a very small amount to prevent b[illegible] or [illegible] opened at intervals to sweep out the accumulated silt before it can build up to intake level.

Fig. 4 shows the modifications made to a small intake on the Sitio River in El Salvador to conform with good practice.

Variations of the standard design are introduced wherever it is not possible to locate the intake high enough above the discharge gate sills. These variations usually consist of submerged training walls or conduits located in front of the intake and upstream from the sluice gates. A recent example of such variation is the intake for the Santa Cecilia pumping station on the Paraiba River in Brazil. Based on tests made at the Iowa Institute of Hydraulic Research an arrangement of three concrete baffles in front of the pump intakes successfully conducts bed load to the sluice gates downstream.

Canals and flumes

The absence of frost makes it possible to use high velocity canals and flumes in the tropics, whereas in cold climates velocities must be kept low enough to permit formation of an ice cover. Likewise it is possible to use lower freeboard allowance for canal embankments where there is no danger of frost penetrating the ground.

On the other hand, the higher rates of runoff in the tropics may make canal design more difficult. Flood waters must be kept out of the canal by entrance control structures, and adjacent hillside drainage must be passed over or under the canal by suitable conduits, whereas in colder climates it is frequently possible to let such drainage enter the canal. Capacities as high as 340 c m. sec. are required for the underpasses and overpasses of the new Nangal canal in India to keep out the adjacent drainage.

Another feature occasionally affecting earth canal design is the prevalance of small burrowing animals. In Indonesia, for example, the yuyu, a kind of crab, digs holes through dikes. Protective coverings or membranes are required to keep them out.

High-line conduits, surge tanks and penstocks

There is little difference in pressure conduit design between the tropics and temperate regions. The planning of such conduits may be simplified by absence of frost in the tropics but, on the other hand, greater allowances for corrosion and erosion may be required.

Surge tanks in hurricane areas require special consideration. After having determined the maximum wind velocity to be expected in the region it is advisable to add a factor of safety to design by omitting any reduction of wind pressure due to curvature of tank surface.

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Powerhouse structures

There is little variation in power house building design in temperate and tropical climates excepting the additional emphasis on ventilation in the latter. Probably the most common problem of the tropics is the necessity of providing protection against high flood water, and more attention is now being given to underground powerhouses on this account. These may be constructed as underground chambers excavated out of the rock or as open pits in the high ground beside the river. The underground powerhouse of the Guayabo Project in El Salvador designed by the Harza Engineering Company to keep out flood water is a unique example of the former. The power station in this case is in a chamber in the rock below the intake. The penstock shafts drop vertically down from behind the headgates to the spiral case inlets of

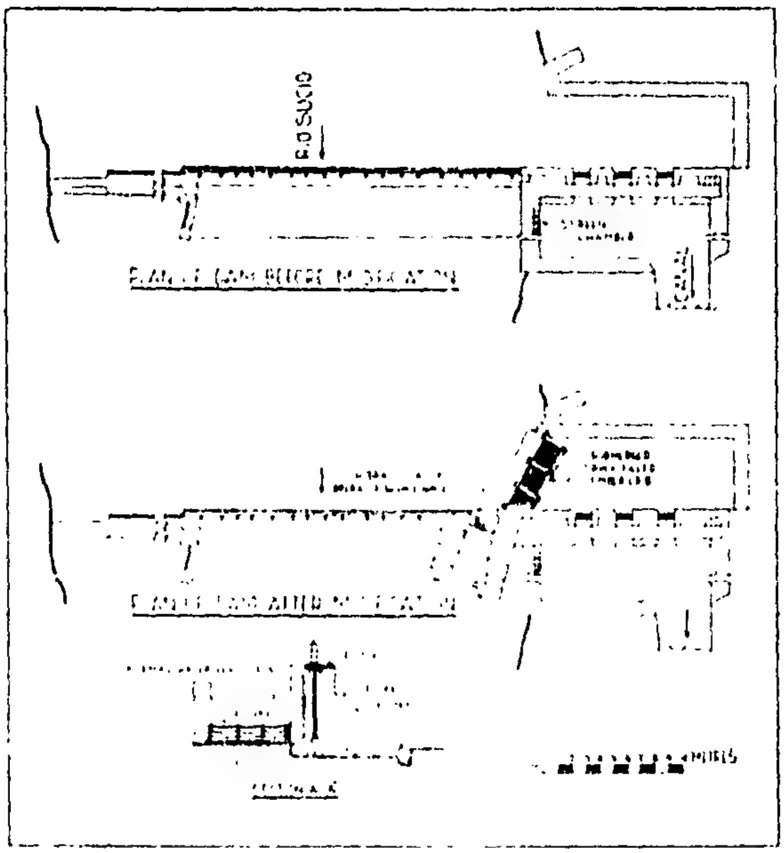

Fig. [illegible] [illegible] dam in El Salvador before and after modification

horizontal Francis turbines on the downstream side of the power station [illegible]al conical tubes discharging into a free-flowing tailrace tunnel

Mechanical and electrical equipment

There is a tendency to greater use of renewable wearing rings in Francis turbines in the tropics than is found in installations further north, but on the whole the specification and design of mechanical and hydraulic equipment is not materially affected by climate. Electrical equipment, on the other hand, should have special design features.

Mid-day temperatures in the tropics may exceed 50°C and the temperature of metal exposed to the sun may go as high as 75°C. Thus a 50°C rise above these ambient conditions would result in equipment temperatures higher than 100°C. Generators, motors and transformers must be provided with adequate ventilation and special insulation if they are to retain their rated capacities under such circumstances. Moreover, if equipment is subject to temperature drops below dew point it should be protected by special tropical impregnations against condensation, and should not contain porous insulating materials which may absorb moisture.

Generators of major installations of say 10,000 KW capacity or over should be provided with closed circuit ventilating systems. Small machines should have ventilation discharge ducts to exhaust the hot air outside the building. Metal-clad switchgear should have ventilation openings at top and bottom of the housings to permit vertical circulation of air, and these openings should be screened against rodents and lizards.

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Summary

Hydro-electric design in tropical and sub-tropical regions as compared to practice in temperate regions is influenced by the high temperatures, extremes of humidity, hurricane winds, high floods, wide variation of streamflow, scarcity of natural storage, and the silt laden river water, frequently encountered in the tropics. Water power in the tropics is usually subordinated to irrigation and most large projects are jointly developed to serve both purposes. However, the greater part of tropical hydro-electric development to date has consisted of small single purpose plants whose popularity is due in part to the greater simplicity of design that is possible when there is no freezing to contend with. Introduction of automatic and remote controlled operation may further improve the position of these small plants.

The design of the various hydraulic structures comprising a power plant — the reservoirs, dams, intakes, canals, flumes, pressure conduits, and surge tanks — is simplified by absence of ice but complicated by high floods and the prevalence of silt in the water. There is little difference in design of buildings and mechanical equipment in hot and cold climates, but design of electrical equipment in the tropics must be adapted to the high temperatures and extremes of humidity. Underground powerhouses will sometimes offer the best means of protecting equipment against the super floods to be expected occasionally on tropical rivers.

Resumen

Los proyectos hidroeléctricos en las regiones tropicales y sub-tropicales, si se comparan con los mismos en las regiones templadas, son influidos grandemente por las altas temperaturas, los extremos de humedad, huracanes, inundaciones, la variabilidad del caudal de los ríos durante el año, escasez de almacenaje natural, y el acarreo fluvial del limo, factores todos muy comunes en las regiones tropicales. La fuerza hidroeléctrica en las regiones tropicales generalmente es subordinada a la irrigación, y la mayoría de los grandes proyectos han sido desarrollados para cumplir ambos propósitos, sin embargo, hasta la fecha la mayoría de las plantas hidroeléctricas en las regiones tropicales

han [illegible] pequeñas plantas cuya popularidad se debe, en gran parte, a la simplicidad de su diseño, la cual es posible cuando no hay congelación contra la cual contender. La introducción del control automático y remoto mejorará, posiblemente, la condición de estas pequeñas plantas.

El diseño de las diferentes estructuras que componen una planta hidroeléctrica, el embalse, la presa, la toma, los canales, las tuberias y el tanque de oscilación, se simplifica debido a que la congelación no existe, pero se complica con la presencia de inundaciones y el acarreo fluvial de limo. Hay muy poca diferencia en el diseño de edificios y equipo mecanizado para climas cálidos o fríos, pero el diseño de equipo eléctrico para los climas tropicales debe de ser adaptado a las altas temperaturas y los extremos de humedad. Una estación de fuerza subterranea ofrece a veces la mejor protección de la instalación contra las crecidas anormales que ocurren en los rios tropicales.

Résumé

Les projets hydro-électriques dans les régions tropicales et subtropicales, si on les compare à ceux des régions tempérées, subissent l'influence des hautes températures, des extrêmes d'humidité, des ouragans, des inondations, de la grande variation du débit des rivières, de la rareté de l'accumulation naturelle et de la quantité de limon fluvial, fréquemment rencontrés sous les tropiques. L'énergie hydraulique dans ces régions est généralement subordonnée à l'irrigation et la plupart des grands projets sont developpés pour répondre à ces deux fins. Jusqu'à présent, cependant, la majorité des usines hydro-électriques dans les regions tropicales a consisté en de petites usines dont la popularité est due en partie à la grande simplicité de leur projet, possible lorsqu'il n'y a pas à lutter contre le gel. L'introduction de contrôle à distance et automatique améliorera, possiblement, la condition de ces petites usines.

Le projet des differentes structures qui composent une usine hydraulique — réservoirs, barrages, chambres d'admission, canalisations, tranchées, conduites de pression et réservoirs d'oscillation — est simplifié par l'absence de glace mais rendu plus compliqué par l'existence d'inondations et la presence de limon dans l'eau. Il y a peu de différence entre le projet de bâtiments et d'equipement mecanisé dans les climats chauds et les climats froids, mais le projet d'equipement electrique sous les tropiques doit être adapté aux hautes temperatures et aux extrêmes d'humidité. Une station de force souterraine offre parfois la protection de l'equipement la meilleure contre les crues anormales des rivières tropicales qui se produisent occasionnellement.

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Titulo 2
Assunto 2 1 2

SCHMIDT (D.)
Suiça

INFLUENCE DES CONDITIONS CLIMATIQUES ET DE LA NATURE DU COMBUSTIBLE SUR LA TURBINE A AIR EN CIRCUIT FERMÉ

Par D. SCHMIDT
COMITÉ NATIONAL SUISSE

La turbine à air en circuit fermé, comme la turbine à vapeur, travaille selon un cycle indépendant de la pression extérieure. Cependant le fluide de travail y reste toujours en phase gazeuse. Il résulte de ces propriétés que l'on peut choisir librement les pressions et les températures du cycle, alors que la turbine à combustion est dépendante de la pression et de la température ambiantes et que, dans le cycle à vapeur, pression et température sont physiquement liées, dans la chaudière et dans le condenseur, par la courbe de saturation.

A l'encontre de la turbine à combustion, le cycle fermé travaille avec une certaine masse de gaz (qui sera le plus souvent de l'air) ne subissant d'échange avec l'atmosphère qu'au cours de variations de densité du fluide moteur, effectué par des organes de réglage pour adapter l'installation à une variation de charge. En effet, la puissance débitée sera d'autant plus élevée que la masse gazeuse en circulation sera plus élevée. Cette variation n'est donc pas obtenue par un réglage de vitesse, mais par un changement du niveau de pression du cycle, indépendamment des températures qui peuvent demeurer constantes; les conditions thermodynamiques de fonctionnement des machines ne sont donc pas troublées par les variations de charge.

L'apport de chaleur est dans ce système toujours indirect; on a donc un circuit de chauffe distinct du cycle proprement dit, exactement comme dans une installation à vapeur, et la combustion étant effectuée avec un minimum d'excès d'air, la quantité de chaleur évacuée par les fumées sera aussi un minimum, ce qui n'est pas le cas dans la turbine à combustion qui exige de 3 à 5 fois plus d'air pour maintenir une température admissible devant la turbine.

CPYRGHT

On voit, dans la figure 1, une disposition schématique comparée du [illegible]mé à air, qui montre l'analogie entre ces deux systèmes. Comme le cycle à vapeur, le cycle à air peut être construit pour un ou plusieurs étages de chauffe. Pour une comparaison plus détaillée, nous renvoyons à la bibliographie à la fin de cet article.

La plus importante des installations actuellement en service est le groupe de 12 500 kW de la centrale de St. Denis représentée à la fig. 2; la pression maximum du circuit est de 50 kg/cm², la température de 665° C devant les turbines.

Une série de groupes de moindre capacité est en construction; ces nouvelles unités sont caractérisées par la simplicité de leur construction et, corrélativement, la facilité du service.

La fig. 3 montre en coupe une machine groupant dans la même carcasse l'ailettage de turbine et les roues de compresseur. Cette construction est employée par exemple pour un groupe d 2 000 kW, chauffé au charbon pulvérisé actuellement en construction, dont on voit la disposition dans la fig. 4. Les groupes présentent par rapport à des installations à

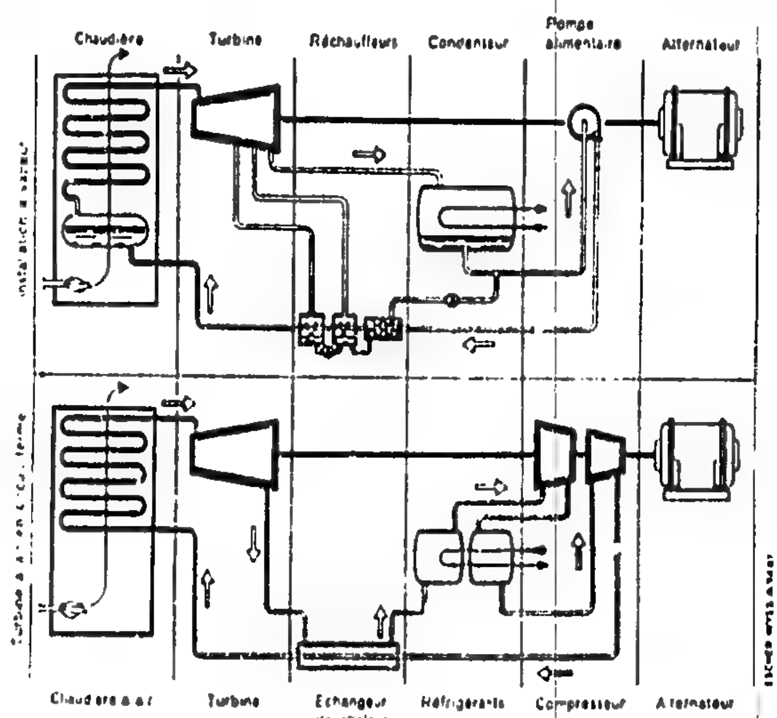

Fig. 1 — La comparaison des schémas d'une installation à vapeur et d'une turbine à air en circuit fermé révèle une grande similitude. Les sections des deux schémas se correspondent.

vapeur de même capacité non seulement l'avantage d'un rendement bien s[illegible] simplification de service et d'entretien:

- pas de préparation d'eau d'appoint,
- consommation bien moindre d'eau de réfrigération,
- pas de souci de désaération, de séparation d'eau et de vidange à la mise en service et à l'arrêt.

On sait que dans la turbine à gaz, de façon générale la puissance utile est donnée par l'excédent de travail des turbines sur le travail absorbé pour la compression du fluide moteur. Or, l'énergie absorbée pour obtenir un certain rapport de compression varie proportionnellement à la température absolue du fluide à l'aspiration des compresseurs. La température d'aspiration aux différents étages de compression étant déterminée par la température d'entrée de l'eau de refroidissement, la température extérieure n'a aucune influence. Cette circonstance est favorable car les variations de température de l'eau sont moins accentuées que celles de l'atmosphère. D'autre part, dans le cycle fermé, il est toujours possible, par une augmentation appropriée du niveau de pression, de compenser la perte de puissance due à une température élevée de l'eau de refroidissement. L'influence de ces conditions sur la consommation spécifique de chaleur est représentée par la figure 5, qui, avec la température d'eau de réfrigération comme paramètre, montre quelle augmentation de pression est nécessaire pour rétablir la puissance nominale.

En partant du point 1 qui correspond à la puissance nominale pour eau de refroidissement à 15°, on voit que si la température de l'eau monte

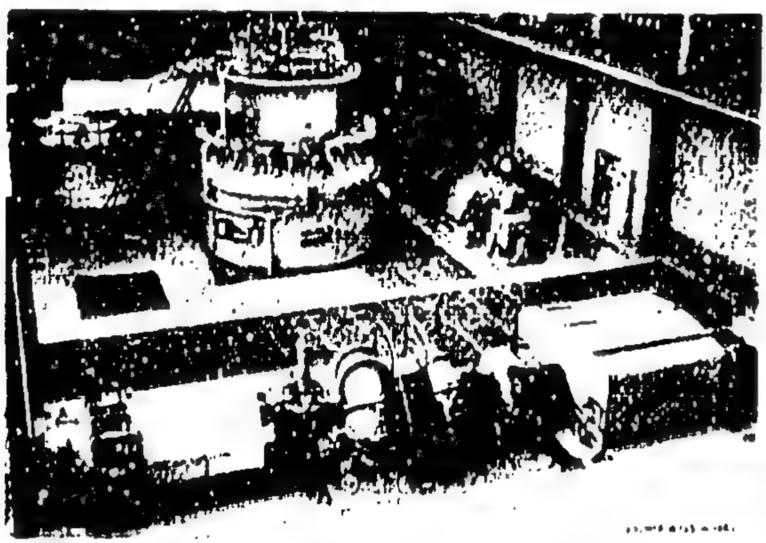

Fig. 2 — Première installation industrielle. Groupe de 12 500 kW installé à la centrale de St. Denis. Un groupe de même puissance, construit par John Brown Co (Clydebank) Ltd., est installé à Dundee.

[illegible] passe de 100 à 85 %; en augmentant le niveau de pression dans la même proportion, par adduction d'air dans le circuit, on rétablit, au point 3, la puissance nominale. Dans les mêmes conditions la perte de puissance pour une turbine à combustion du type le plus simple est de 18 %. (1)

D'autre part, la variation de pression atmosphérique avec l'altitude ne modifie évidemment en rien la capacité du circuit fermé, dont le niveau est réglable, alors qu'une turbine à combustion perd par exemple à 3 000 m d'altitude environ 30 % de sa puissance.

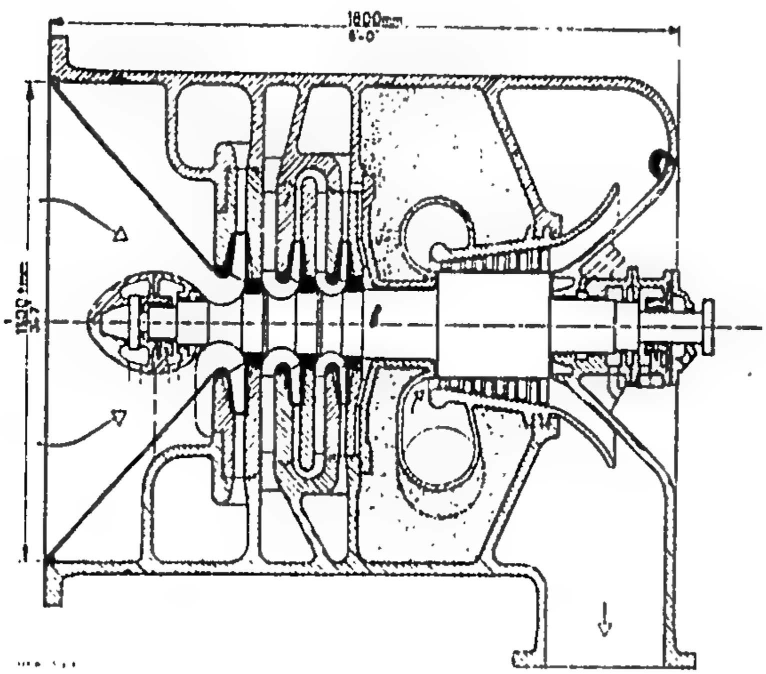

Fig. 3 — Turbine et compresseur d'une installation de turbine à air en circuit fermé combinés en un seul element. Cette construction est extremement compacte et permet une réduction considerable du prix et de l'encombrement.

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(1) "Gas Turbines and Centrifugal Compressors" by F. R. Rhea and J. S. Quill, Mechanical Engineering, July 1958

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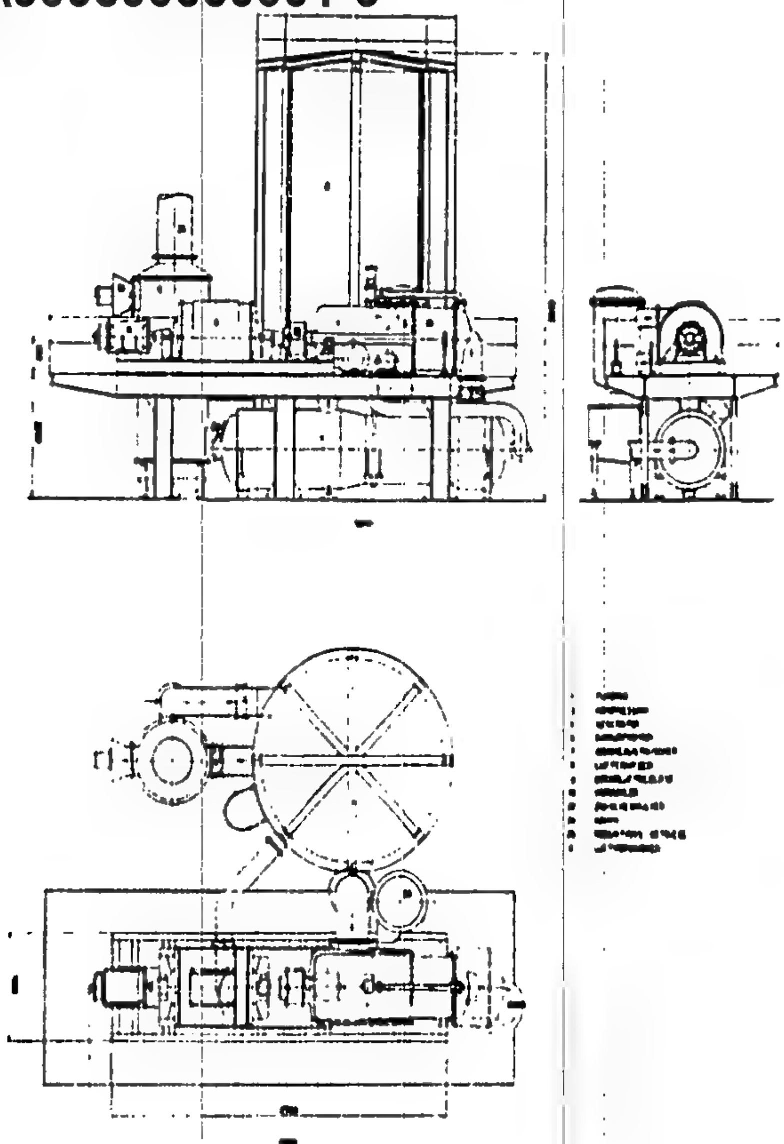

Fig. 4

IMPURETÉ DE L'AIR ET HUMIDITÉ

L'air aspiré de l'extérieur pour la mise sous pression du circuit est filtré; il en est de même de l'air d'appoint nécessaire à la compensation des fuites, qui n'atteignent d'ailleurs que quelques dixièmes de pour-cent de la circulation d'air à travers le circuit fermé. Il peut aussi être avantageux dans certains cas de sécher l'air d'appoint avant son introduction dans le circuit; cette mesure se justifie ainsi:

L'air aspiré de l'extérieur contient une proportion d'eau pouvant atteindre, dans un climat chaud et humide, 2 à 3% en poids. Cette eau se trouve sous forme de vapeur mélangée à l'air; selon la règle de Dalton son équilibre physique est déterminé par la pression partielle de vapeur, c.à.d. par la quantité de molécules d'eau contenue dans un certain volume et par la fonction pression-température caractérisant la saturation de la vapeur d'eau. Or si l'on comprime une vapeur à température constante, on se rapproche de la ligne de saturation et, en l'atteignant, on obtient une condensation partielle de la vapeur d'eau. Ce dernier cas se produit dans les réfrigérants intermédiaires des compresseurs qui, sous une pression élevée, ramènent le fluide de travail à une température voisine de la température ambiante. Les gouttelettes d'eau ainsi formées peuvent en partie se déposer sur les surfaces de refroidissement; si elles sont entraînées dans l'étage de compression suivant, l'élévation de température due à la compression les ramène tout de suite à l'état de vapeur.

Dans le circuit fermé on peut constater parfois une condensation d'une partie de l'humidité selon le processus expliqué ci-dessus. Toutefois, il ne peut s'agir que de quantités minimes. On a calculé par exemple pour un cas extrême une condensation possible de 10 kg par heure pour une installation en circuit fermé de 12 000 kW, et, en partant des mêmes conditions, on arrive pour le circuit ouvert à une masse d'eau de 3 tonnes par heure pouvant être condensée dans les réfrigérants, ce qui peut troubler gravement le fontionnement de cet appareil.

Le circuit fermé évite naturellement aussi l'absorption de grandes quantités de vapeurs d'huile, de poussières et d'impuretés qui, par encrassement des aubages, provoquent une diminution de rendement et de puissance, comme l'ont constaté tous les constructeurs de turbines à gaz. On voit dans la fig. 6 (2) l'effet de l'encrassement sur le rendement d'une turbine à combustion selon les mesures de John Brown.

En ce qui concerne l'air de combustion et les fumées qui, dans l'installation en circuit fermé, ne sont pas en contact avec le fluide de travail, les conditions atmosphériques et les poussières ne posent pas de problèmes particuliers, ainsi que le montre l'expérience d'exploitation des chaudières à vapeur. Il en est autrement de l'action des produits de la combustion, dont les effets nocifs peuvent être classés en:

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(2) Experimental Running of Open — and Closed — Cycle Gas Turbines, by J. B. Bucher, Paper No. 1125, The Institution of Engineers and Shipbuilders in Scotland.

1) attaque mécanique (érosion)

2) attaque chimique (corrosion)

3) encrassement.

1) *Érosion*

L'expérience a montré qu'une attaque mécanique par les cendres est possible dès que des particules de masse suffisante rencontrent à grande vitesse les surfaces considérées.

Dans les machines, et en particulier les aubages de turbines, on ne peut éviter des vitesses élevées, de telle sorte que l'utilisation de certains combustibles solides dans une turbine à combustion reste très problématique, car on ne connait pas d'organes séparateurs efficaces supportant des températures de 600 à 700° C. L'installation à circuit fermé n'est par contre pas exposée à ce danger, puisque dans l'appareil de chauffe les vitesses des gaz de combustion sont modérées.

2) *Corrosion*

La seule crainte manifestée en ce qui concerne l'attaque chimique est due à l'action du vanadium contenu dans certaines huiles lourdes lorsque des cendres en fusion se déposent sur des surfaces métalliques portées

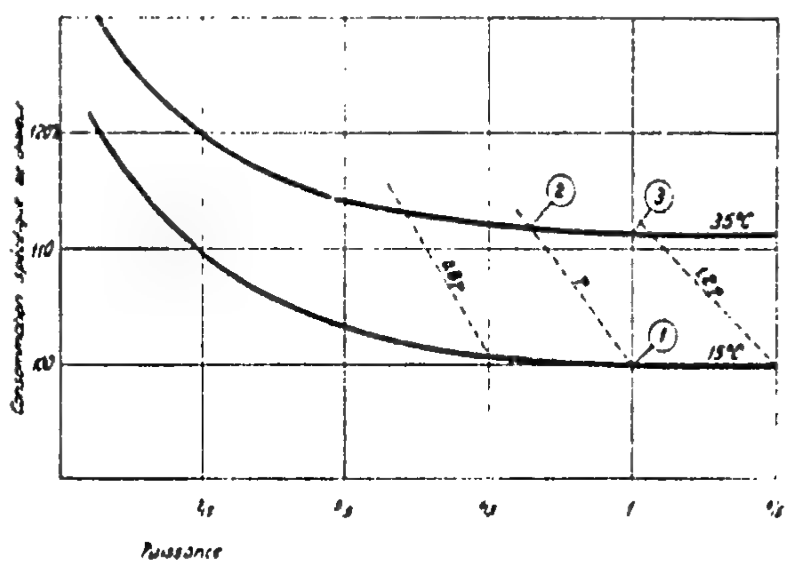

Fig. 5 — Consommation de chaleur en fonction de la charge pour eau de réfrigération à 15° et à 35° C.
. . . . lignes de pression constante devant la turbine.

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à une température supérieure à 600° C. Etant donné que le rendement [illegible] est lié à l'emploi de hautes températures, on comprend que ce problème ait fait l'objet d'études très poussées. On a déterminé d'une part la sensibilité à cette action des divers aciers réfractaires utilisés dans la construction des turbines à gaz et, d'autre part, on a cherché par des additifs à prévenir cette action chimique. Ce dernier moyen, s'il résout en principe la question, présente par contre des inconvénients pratiques: complication, prix de revient, encrassement. On peut espérer que dans le cas du cycle fermé à air, où les gaz de combustion ne sont pas en contact avec les aubages des turbines, la solution du problème est facile; il est en effet possible d'éviter que les cendres en fusion se précipitent sur les tubes dans la zone de haute température de l'appareil de chauffe. La figure 7 représente l'échaufleur d'air d'une installation industrielle de 2000 kW chauffée au mazout; la plus grande partie de la chaleur y est transmise par radiation dans une chambre de combustion cylindrique largement dimensionnée. Ce type d'échaufleur d'air convient aussi pour la chauffe au charbon pulvérisé, à la tourbe, au lignite etc.. Il ressemble aux appareils de construction américaine utilisés en très grand nombre par l'industrie pétrolière. Pour les combustibles très chargés en humidité, tels que la tourbe, une méthode de séchage et de broyage parfaitement efficace a été mise au point par John Brown. (3) Un groupe de 2000 kW, chauffé à la tourbe, est en construction en Angleterre.

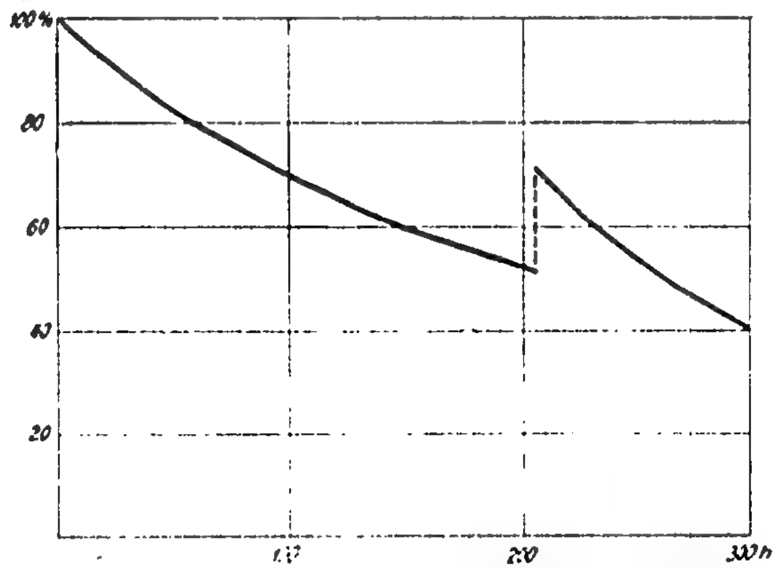

Fig. 6 — Perte de puissance d'une turbine à combustion par suite d'encrassement de la turbine et du compresseur, selon les mesures de John Brown. Après 210 heures de marche on a procédé a un lavage du compresseur.

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(3) "Successful tests of a Peat burning Turbine", The Oil Engine, January 1952.

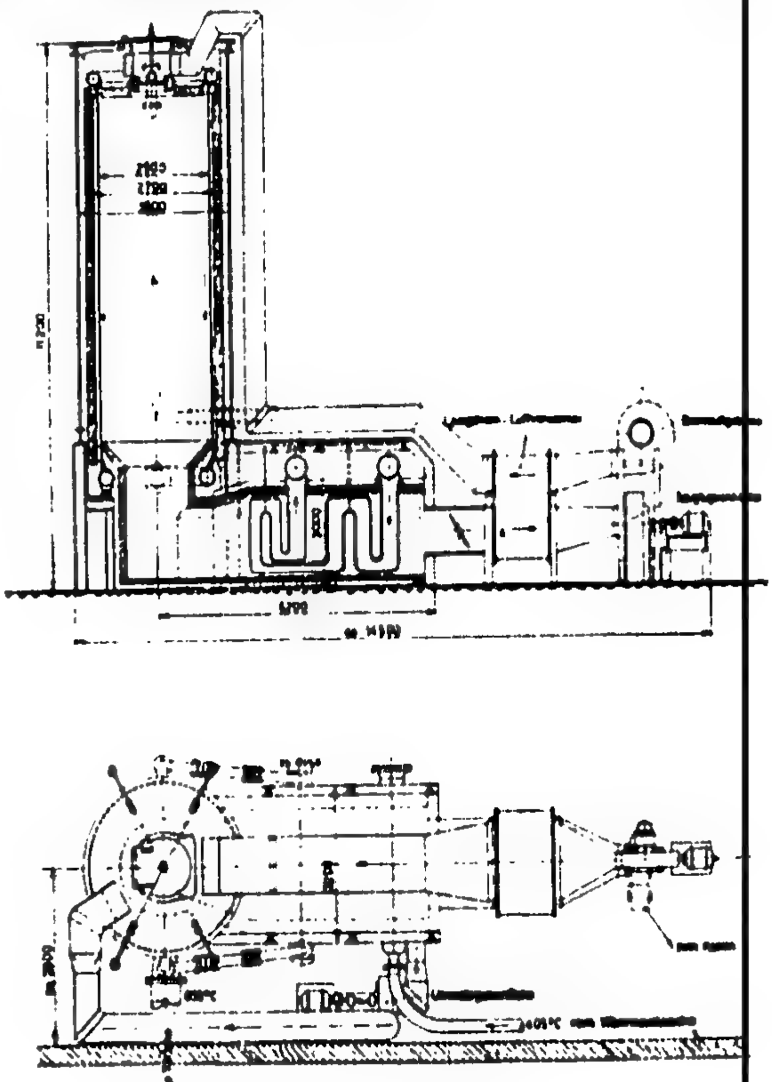

Fig. 7

b) *Enc*[illegible]

[illegible] proprement dit l'encrassement est exclu, ce qui est un grand avantage par rapport au circuit ouvert. (¹) Seul l'appareil de chauffe peut y être sujet. L'expérience a montré que la température relativement élevée des tubes a un effet favorable sur la combustion. Dans le cas de chauffe au fuel-oil, des dépôts se forment dans le réchauffeur d'air de combustion, où la température est basse; ces dépôts sont facilement enlevés par lavage à l'eau chaude. Avec le charbon pulvérisé, la tourbe, le lignite, on aura recours à la technique des chaudières à vapeur pour le soufflage des suies.

Dans beaucoup d'exploitations industrielles une quantité de chaleur importante est libérée sous forme de gaz chauds incombustibles contenant beaucoup d'impuretés (convertisseurs, fours à pyrite, etc.) Cette chaleur ne peut être utilisée à la production d'énergie électrique que par un groupe thermique à chauffage indirect, par exemple un groupe à vapeur ou une turbine à gaz en circuit fermé. Le plus souvent la puissance réalisable ne dépasse pas 1000 à 2000 KW. On conçoit qu'il n'est pas question, pour cet ordre de grandeur, d'installation à vapeur à haut rendement. Avec la turbine à air en circuit fermé au contraire, il est possible de produire un maximum d'énergie électrique avec une installation simple.

Pour les appareils du circuit fermé qui sont parcourus par un fluide propre on a toute liberté de profiter des avantages que donnent les éléments d'échange de chaleur de très petites dimensions, c.à.d. une grande efficacité sous un volume restreint (tubes de quelques millimètres de diamètre, surfaces ailettées, etc.). On voit dans la fig. 8 une section d'un échangeur de chaleur; à l'intérieur des tubes circule l'air du circuit fermé après sa compression et à l'extérieur passe l'air après sa détente dans la turbine.

EAU DE RÉFRIGÉRATION

Les centrales thermiques sont placées en principe soit près de la source de combustible, soit au centre de la région alimentée en énergie. Mais de toute façon, la mise à disposition de la masse considérable d'eau de refroidissement d'une centrale à vapeur impose une servitude souvent sévère. Lorsqu'on ne peut disposer du débit d'eau fraîche nécessaire, on est obligé de faire circuler l'eau dans un circuit fermé comprenant les condenseurs et une tour de réfrigération; on ne consomme alors que l'eau d'appoint perdue dans la tour par évaporation. Cette chaleur d'évaporation est pratiquement égale aux calories échangées dans les condenseurs. On n'obtient toutefois pas par ce procédé un vide aussi poussé qu'avec la circulation d'eau fraîche dans les condenseurs.

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(1) "Fuel-oil Ash Deposition in Open-cycle Plant". The Oil Engine, May 1953

[illegible] en circuit fermé le nombre de calories à [illegible] même que dans une turbine à conden[illegible] cependant sous une forme différente: alors que dans un condenseur l'eau de réfrigération ne peut être chauffée de plus de quelques degrés sans perte sensible de vide à la sortie de la turbine, étant donné qu'à chaque température de vapeur correspond une certaine pression de saturation, il en est tout autrement dans un réfrigérant de turbine à gaz où le fluide moteur en phase gazeuse est refroidi par exemple de 100° C. à 30° C.; en disposant la circulation d'eau en contre-courant on peut admettre un réchauffage de cette eau par exemple de 20° C. à 50° C., ce qui réduit le débit à un quart de ce qui est nécessaire à une installation à vapeur. Il faut naturellement considérer soigneusement les caractéristiques de l'eau utilisée au point de vue de la formation de dépôts minéraux et biologiques. Dans certains

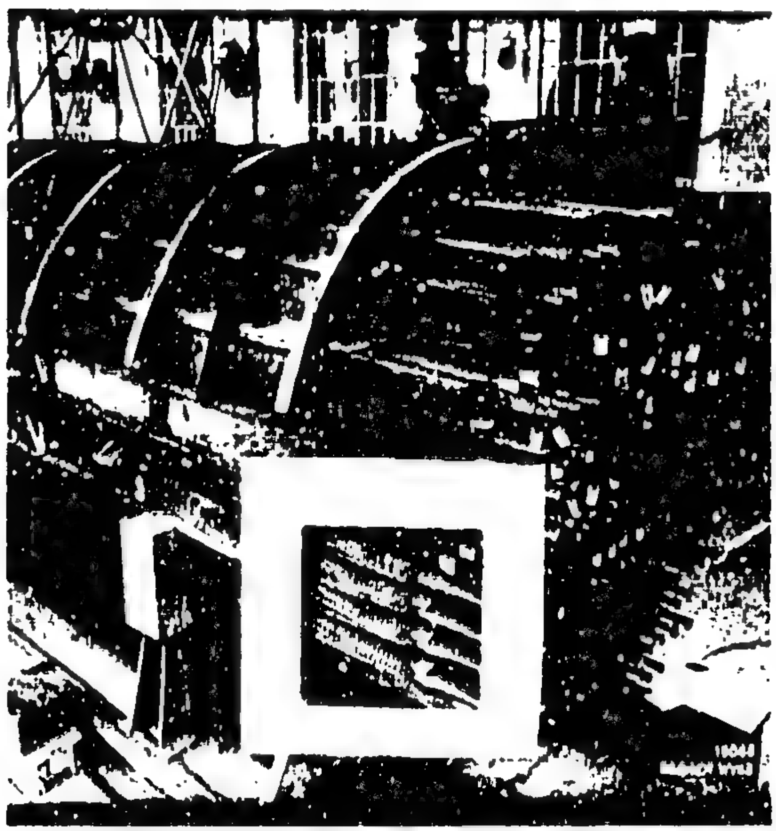

Fig. h — Éléments tubulaires d'échange de chaleur du circuit fermé. Le diamètre extérieur des tubes est de [illegible]

[illegible] devrait [illegible]
[illegible] l'eau de [illegible]

Dans les cas extrêmes la turbine à gaz peut [illegible] de réfrigération en circuit fermé qui sera [illegible] que pour une installation à vapeur. Enfin on peut envisager [illegible] petits groupes installés dans des régions désertiques des [illegible] air activés par un ventilateur, de cette façon [illegible] d'eau de réfrigération.

Il sera souvent intéressant de réduire le débit d'eau non pas pour en économiser la consommation, mais pour obtenir une température d'eau à la sortie des réfrigérants permettant de l'utiliser pour le chauffage des habitations, on pourra aussi dans ce cas faire circuler l'eau en circuit fermé entre les réfrigérants de la turbine à gaz et les corps de chauffe des bâtiments. Un second circuit peut amener de l'eau fraîche à ces réfrigérants de façon à ce que la production d'énergie ne soit pas [illegible] amoindrie. L'eau du circuit fermé est alors refroidie d'abord par [illegible] de chauffage, puis par l'eau fraîche.

L'économie de cette solution est extrêmement satisfaisante puisque la chaleur pour le chauffage est livrée en quelque sorte gratuitement au cours de la production d'électricité. Ainsi un groupe de 2000 kW peut à la fois couvrir les besoins d'énergie électrique et une bonne partie du chauffage d'une petite ville ou d'une usine, en donnant 2 Mio de calories par heure pour le chauffage des locaux; ce débit de chaleur peut être porté à [illegible] Mio de calories par heure dans la période des grands froids.

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RÉSUMÉ

On a tout d'abord rappelé le principe de la turbine à air en circuit fermé et les avantages manifestes de ce système qui, proposé par le Prof.

[illegible] circuit fermé [illegible] Escher Wyss [illegible] [illegible] turbine [illegible] sont indépendantes des conditions ambiantes de pression et de température. Seule la température de l'eau de refroidissement a une influence prépondérante sur le rendement thermique; cependant grâce à la possibilité de variation du niveau de pression, la puissance nominale peut toujours être atteinte.

Enfin on a considéré l'influence des impuretés et de l'humidité atmosphériques qui ne sont pas à craindre comme dans le cas de la turbine à combustion et on a indiqué les conditions à observer pour l'utilisation des combustibles liquides et solides.

Summary

The basic data of the closed cycle gas turbine and its obvious advantages are first shortly resumed. This type of machine, which has been proposed by Prof. J. Ackeret and Dr. C. Keller, has now attained the practical industrial stage, thanks to the development work of Messrs. Escher Wyss Ltd. and their licencees.

As for the steam turbine the ambient conditions of pressure and temperature have no influence on this machine. Only the cooling water temperature has an overwhelming influence on the thermal efficiency. Anyhow, as the pressure level in the plant can be controlled it is possible to obtain the nominal output in any conditions.

No bad effect due to dust and air humidity is to be feared as in the combustion turbine. The main conditions to be considered in the use of liquid and solid fuels have been pointed out.

Resumen

En primer lugar se ponen de manifiesto los principios fundamentales de la turbina de gas de circuito cerrado así como las ventajas inequívocas de este sistema. Este tipo de máquina, presentado por los señores Prof. J. Ackeret y Dr. C. Keller, ha alcanzado ahora la etapa de la explotación industrial, gracias al trabajo de la casa Escher Wyss, S. A. y de sus concesionarios.

Al igual que la turbina de vapor, esta máquina es prácticamente independiente de las condiciones exteriores de presión y de temperatura. Sólo la temperatura del agua de refrigeración ejerce una influencia determinante sobre el rendimiento. Por lo demás, la potencia nominal puede alcanzarse en todo momento variando el nivel de la presión.

Finalmente, se ha tratado de los efectos de la humedad y de la contaminación del aire que, al contrario de lo que sucede con la turbina de combustión, no se deben temer en esta máquina. Las condiciones para el empleo de los combustibles líquidos y sólidos han sido también mencionadas.

CONFERÊNCIA MUNDIAL DA ENERGIA
WORLD POWER CONFERENCE

REUNIÃO PARCIAL
SECTIONAL MEETING
Rio de Janeiro — [illegible]

[illegible]

O APROVEITAMENTO HIDROELÉCTRICO DO DOURO INTERNACIONAL

Por PEDRO A. NUNES
[illegible]

COMITÉ NACIONAL PORTUGUÊS

O APROVEITAMENTO HIDROELÉCTRICO DO DOURO INTERNACIONAL

1. O rio Douro tem a sua nascente nos Montes Ibéricos, em Espanha. Dentro deste país, desenvolve-se numa extensão de [illegible] km, drenando uma bacia hidrográfica de [illegible].

Neste primeiro troço [illegible] de extensão em que serve de fronteira entre Portugal e Espanha, depois do que o rio corre 213 km dentro de Portugal. Neste [illegible] na costa atlântica a sua foz.

A definição do troço em que o Douro serve de fronteira data do tratado de limites entre Portugal e Espanha celebrado em 1864. Nos próprios termos deste tratado [illegible] a linha internacional vai pelo centro da corrente principal do Douro [illegible]. Neste tratado ficou desde logo exarado que "atendendo a que a linha internacional segue em várias partes cursos de água, [illegible] convenciona-se em que os cursos de água [illegible] que se acham no indicado caso sejam de uso comum para os povos de ambos os Reinos". Em 1866, um "Anexo" a este tratado confirmou, mais especificadamente do ponto de vista jurídico, que "os rios que servem de fronteira [illegible], sem prejuízo de pertencerem a ambas as nações pela metade das respectivas correntes, serão de uso comum para os povos dos dois países".

O troço fronteiriço do Douro, correntemente designado por Douro Internacional, inclui-se num dos troços bastante distintos em que se divide o perfil longitudinal do Rio, caracterizado pelo forte declive médio de 3 m por km e por um perfil transversal constantemente encaixado. Apenas a parte final deste troço internacional, compreendida entre as

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] Portugal do direito de utilizar [illegible] integral [illegible] espanhol [illegible] parte de jusante

Em cada troço dos [illegible] de aproveitamento assim definido, o Estado ao qual é atribuído tem o direito de utilizar para a produção de energia eléctrica todo o caudal que corre.

As determinantes deste modo de efectuar a divisão terão sido, sem dúvida, as seguintes: A feição em ravina do perfil transversal e o forte declive do perfil longitudinal do Rio tornam inviável o estabelecimento de albufeiras com capacidade de regularização apreciável, em face dos caudais integrais anuais. As obras a estabelecer têm por isso que ter um carácter essencialmente a fio de água, não se levantando portanto qual

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[illegible]

Note-se que o princípio básico de divisão [illegible], adoptado para a resolução do problema do aproveitamento hidroeléctrico, não se estende aos outros direitos territoriais. Esclareceu de facto o Convénio que "todos os demais direitos de cada Estado limítrofe sobre o referido troço internacional, definidos no tratado de limites de 1864 e no seu anexo [illegible], ficam subsistindo em tudo que não contrarie a aplicação das regras estabelecidas no presente Convénio". E insiste em que a "jurisdição de cada Estado no troço internacional conservará o limite fixado no [illegible] Tratado de 1864. O referido limite fica equidistante nos diques, das duas extremidades e nas alfândegas das duas margens.

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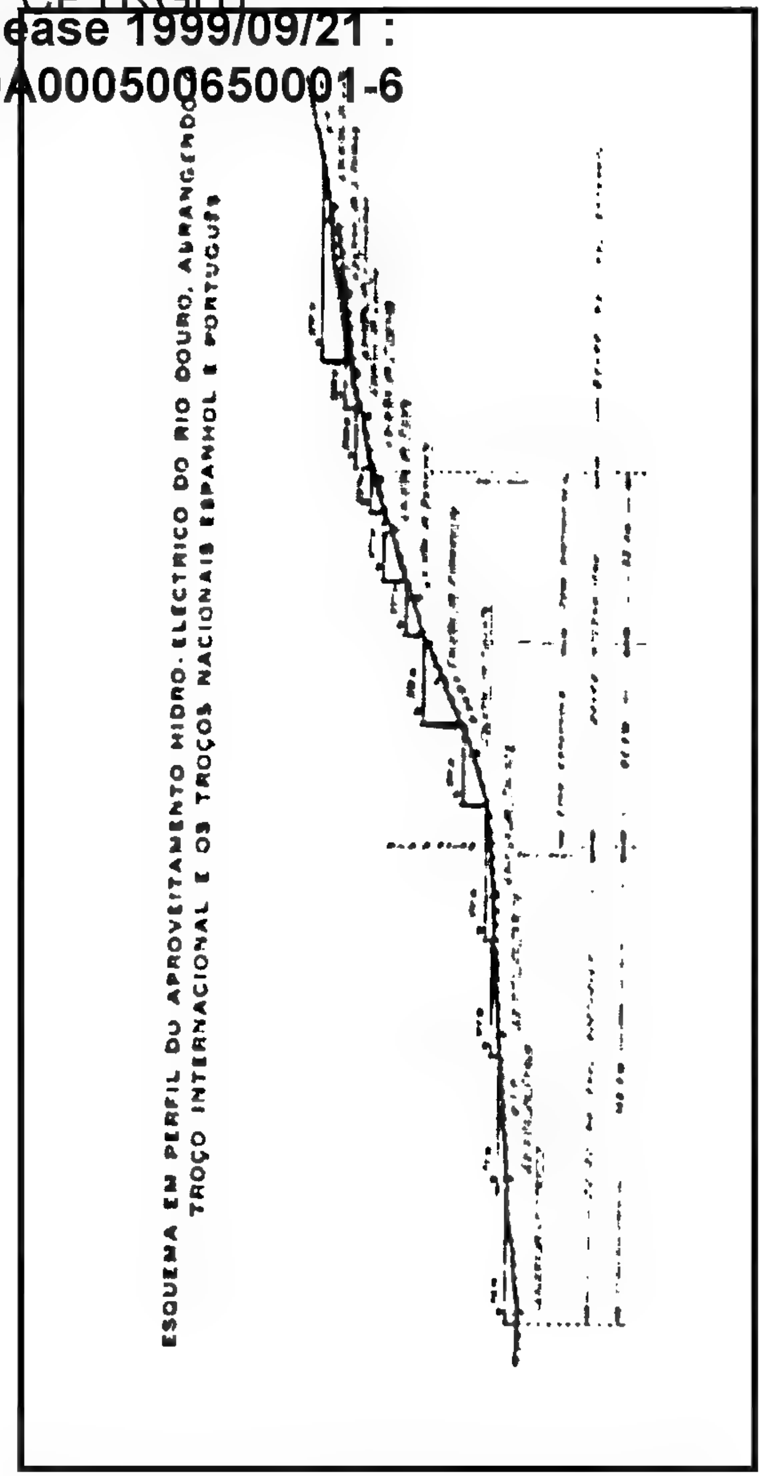
ESQUEMA EM PERFIL DO APROVEITAMENTO HIDRO-ELECTRICO DO RIO DOURO, ABRANGENDO O
TROÇO INTERNACIONAL E OS TROÇOS NACIONAIS ESPANHOL E PORTUGUÊS

[illegible] ... quela disposição do Convénio.

7. Para se facilitar a aplicação prática do Convénio, fixou este [illegible] a criação duma comissão permanente composta por igual número de representantes (hoje quatro) de cada um dos dois Governos português e espanhol. Esta Comissão tem especialmente a função de regular o exercício dos direitos bilaterais reconhecidos e de dirimir as questões jurídicas ou técnicas por ele suscitadas.

Esta comissão só veio a ser constituída em 1962 quando a proximidade do início dos trabalhos de construção do primeiro escalão de aproveitamento espanhol — Saucelle — o tornou oportuno.

Até hoje celebraram-se duas reuniões, respectivamente em Janeiro de 1963 e Janeiro-Fevereiro de 1964. Nessas reuniões foram especialmente tratados, em plenário ou através de subcomissões, os seguintes pontos:

a) Elaboração do Estatuto da Comissão e constituição de subcomissões;

b) Regulamentação das expropriações, servidões e ocupações temporárias;

c) Regulamentação das normas de aprovação dos projectos das obras;

d) Condições técnicas especiais a que deverão obedecer os projectos das obras, de modo a assegurar-se o cumprimento dos princípios fixados no Convénio;

e) Delimitação rigorosa [illegible] das duas zonas de aproveitamento;

f) Eventual modificação do Convénio no sentido de se tornar possível a construção de centrais [illegible] o curso do Rio;

g) Neutralização aduaneira das zonas de obras.

Citaremos, a seguir, alguns dos problemas cuja solução tem sido visada na orientação dada aos temas atrás enumerados.

8. Convém assegurar que quaisquer irregularidades de funcionamento duma central, situada na origem da zona atribuída a um dos países, se não repercutirão no regimen dos níveis de água no canal de fuga da central, pertencente ao outro país, situada imediatamente a montante. Neste sentido, assentou-se que as albufeiras dos escalões de origem de zona serão providas de órgãos automáticos de descarga com capacidade não inferior à da admissão das turbinas das respectivas centrais.

Igualmente, em relação com a capacidade de evacuação das cheias nas albufeiras de origem de zona, acordou-se que deverá ficar garantido, nos respectivos projectos, que a curva de regolfo não ultrapasse em termos apreciáveis a cota natural da cheia na origem da zona. Isto não

[illegible] capacidade [illegible] nas ocasiões de cheia.

9. A circunstância de se tratar de aproveitamentos [illegible] praticamente a fio de água em face das variações sazonais de caudal não impede todavia que se lhes atribua uma certa capacidade de adaptação às variações horárias e de fim de semana do consumo. Importa porém garantir que essa adaptação não seja levada a um ponto tal que se levantem dificuldades à exploração dos aproveitamentos situados na zona a jusante.

Assim, assentou-se já que os projectos devem prever que, fora das ocasiões de cheia, os caudais integrais afluídos à origem duma zona, durante uma semana, serão devolvidos à zona de jusante dentro da mesma semana.

10. As expressões usadas no Convénio para as delimitações das duas zonas de aproveitamento são deste teor: "... o desnível do rio na zona compreendida entre ... e ...".

Quais as cotas altimétricas que, respeitando estes termos, poderão ser tomadas para definição do nível de retenção normal dum aproveitamento situado na origem duma zona? É o caso dos escalões de Miranda do Douro e de Pocinho para Portugal e de Aldeadávila para Espanha.

No âmbito da Subcomissão de delimitação dos troços está, de momento, assente o critério de que essas cotas de retenção normal sejam fixadas tendo presente que o caudal turbinado em qualquer das centrais, pela própria conveniência da exploração, nunca descerá de uma fracção muito pequena do caudal correspondente à potência nominal dum grupo. Ora esta potência unitária está prevista, para qualquer das centrais, numa ordem de grandeza correspondente a um caudal turbinado de 100 m^3/s.

Isto é também evidentemente uma consequência da regularização de caudal devida à albufeira espanhola de Ricobayo no afluente Esla, que está em exploração desde [illegible]. E esta regularização foi, de certo modo, oficializada pelo próprio Convénio, que estabeleceu que as obras de aproveitamento do Douro em Espanha "directamente destinadas à regularização do Douro no seu troço internacional ... começaram pela construção, no rio Esla, do dique chamado de Ricobayo".

A não utilização nas centrais de caudais pequenos acarreta o estabelecimento, nos respectivos canais de fuga, duma altura de água apreciável que pode atingir 2 m acima da cota que corresponderia a uma estiagem extrema. Há portanto, do ponto de vista prático, interesse para ambos os países, em que as cotas de retenção normal dos escalões de origem de zona sejam fixadas com base em níveis de água francamente superiores aos de estiagem.

A Subcomissão resolveu que se dê início com urgência aos trabalhos de campo necessários à delimitação rigorosa, em altimetria, das zonas com base neste critério.

[illegible] consequência do espírito, que atrás assinalámos de salva[illegible] do Estado, sobre a metade adjacente do leito [illegible] do Rio, foi a inclusão, no Convénio, duma cláusula estabelecendo que "as tomadas de água, canais, edifícios e em geral todas as obras e instalações precisas para a utilização de cada zona serão situadas no território nacional do Estado a que pertença o aproveitamento, com excepção dos diques e das obras de desaguamento ou outras acessórias que tenham necessàriamente de ser construídas no leito ou na margem do rio pertencente ao outro Estado".

Esta prescrição é compreensível se tivermos presente a tendência, que na época em que ela foi formulada predominava, para a adopção, em condições como as do Douro Internacional, de esquemas de aproveitamento com canais de derivação extensos.

Hoje, o conjunto de considerações técnicas e económicas — em que se destaca o princípio de máxima utilização das quedas disponíveis — leva à adopção de escalões do tipo central de pé de barragem. Ora, não estaria fora de tendências construtivas actuais o estabelecimento de centrais deste tipo, n'algum dos escalões do Douro Internacional, em que a concentração das obras fosse conduzida em termos de o edifício da central, por uma íntima conexão com a estrutura da barragem, ultrapassar o limite territorial, definido pelo eixo do rio.

Actualmente, o Convénio, como se acaba de mostrar, não permitiria a aprovação dum projecto nestas condições. A Comissão já deliberou, porém, informar os Governos dos dois países de que julga conveniente que seja considerada, pela via diplomática, a eventual modificação do Convénio no sentido de se eliminar tal impedimento.

Resumo

O rio Douro serve de fronteira entre Portugal e Espanha, num troço com 112 km de extensão e 402 m de desnível, ao longo do qual a respectiva bacia hidrográfica passa de 68 200 para 75 300 km².

O direito de utilização deste troço internacional do Douro foi regulado duma maneira definitiva por um Convénio, assinado em 1927 entre os Governos dos dois países. As características morfológicas do Rio facilitaram a adopção, para esse efeito, dum esquema simples.

Considerou-se o troço internacional fraccionado em duas partes, a que correspondem desníveis sensìvelmente iguais, pela confluência do afluente Tormes. A Portugal foi atribuído o direito de utilização da parte situada a montante dessa confluência, e à Espanha o de utilização da parte situada a jusante. Este último país pode assim beneficiar, no aproveitamento do Douro Internacional, do acréscimo de caudal correspondente à bacia do afluente Tormes, que se desenvolve inteiramente em território espanhol e oferece apreciáveis qualidades de regularização, por albufeiras, do seu caudal anual.

Na monografia descrevem-se os seguintes aspectos particulares das disposições do Convénio ou surgidos na sua aplicação prática:

a) proibição de derivação de caudais — mesmo sobrantes — para bacias laterais;

b) garantia de que o regolfo das cheias ou quaisquer irregularidades do funcionamento duma central, situada na origem da zona atribuída a um dos países, se não repercutirão no regímen dos níveis de água no canal de fuga da central, pertencente ao outro país, situada imediatamente a montante;

c) limitação das possibilidades de regularização semanal, dentro das centrais dum país, de modo a não se dificultar a exploração das centrais do outro país, situadas a jusante;

d) fixação dos limites altimétricos da zona de utilização de cada país, tendo em conta as alturas de água, nos canais de fuga, correspondentes aos caudais mínimos turbináveis;

e) possibilidade de as tomadas de água e edifícios das centrais serem instalados além do limite territorial definido pelo eixo do Rio.

Résumé

Le fleuve Douro sert de frontière entre le Portugal et l'Espagne dans un tronçon de 112 km de longueur et 102 m de dénivellation, le long duquel son bassin hydrographique passe de 63 200 à 75 300 km².

Le droit à l'utilisation de ce tronçon international du Douro a été réglé, d'une façon définitive, par une Convention, signée en 1921, par les Gouvernements des deux pays. Les caractéristiques morphologiques du fleuve ont facilité l'adoption, à cet effet, d'un schéma simple.

On a considéré le tronçon international divisé en deux parties, auxquelles correspondent sensiblement les mêmes dénivellations, au moyen du confluent de l'affluent Tormes. Le droit à l'utilisation de la partie située en amont de ce confluent a été attribué au Portugal et celui de la partie située en aval, à l'Espagne. Ce dernier pays est ainsi en mesure de pouvoir profiter, à l'aménagement du Douro International, du surcroît de débit correspondant au bassin de l'affluent Tormes, qui s'étend tout en territoire espagnol et offre des possibilités appréciables de régularisation de son débit annuel, par réservoirs.

Dans la monographie sont décrits les aspects particuliers suivants des dispositions de la Convention, ou bien nés de son application pratique:

a) défense de déviation de débits — même si excédents — dans des bassins latéraux;

b) garantie que le remous des crues ou d'autres irrégularités du fonctionnement d'une usine, située au début de la zone attribuée à l'un des pays, ne se répercutiront pas au régime des niveaux d'eau au canal de fuite de l'usine appartenant à l'autre pays et située immédiatement en amont;

c) limitation des possibilités de régularisation hebdomadaire dans les [illegible] ne pas rendre difficile l'exploitation des usines de l'autre pays, situées en aval;

d) fixation des limites altimétriques de la zone d'utilisation de chaque pays, en tenant compte des hauteurs d'eau aux canals de fuite, correspondants aux débits minima turbinables,

e) possibilité d'installer les prises d'eau et les édifices des usines au delà du limite territorial défini par l'axe du fleuve.

SUMMARY

The river Douro serves as the border between Portugal and Spain in a reach 112 km long and 102 m drop, along which its watershed passes from 63 200 up to 75 300 sq. km.

The right for use of the Douro international reach was ruled in a definitive way by a Convention, signed in 1921, between the Governments of the two countries. The morphologic characteristics of the river made easy the adoption of a simple scheme for this purpose.

The international reach was divided in two parts, corresponding approximately to the same drop, by means of the confluence of the tributary Tormes. The right for use of the part upstream this confluence was granted to Portugal and the part placed downstream to Spain. Thus, this latter country, in the development of the International Douro, can take advantage of the increase of flow corresponding to the tributary Tormes watershed, which entirely stretchs in Spanish territory and offers considerable possibilities for regulation of its annual flow, by means of reservoirs.

In the monograph the following peculiar aspects of the Convention stipulations or born from its practical use are described:

a) forbidding of diversion of the stream flow — even when surplus — into lateral basins;

b) guaranty that the backwater or any operation irregularity of a powerhouse, placed at the beginning of the zone granted to one of the countries, shall not repercuss in the tailwater regimen of a powerhouse belonging to the other country and placed upstream;

c) limitation of week regulation possibilities in the powerhouse of a country, in order that the operation of powerhouses, belonging to the other country and placed downstream, is not made difficult;

d) definition of elevation limits of the part which can be used by each country, bearing in mind the water elevations in tailraces, corresponding to minima used flows;

e) possibilities for intakes and powerhouses to be placed beyond the territorial limits defined by the river axis.

CONFERENCIA MUNDIAL DA ENERGIA
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Assunto 1.1

REUNIÃO PARCIAL
SECTIONAL MEETING
Rio de Janeiro — 1954

CUEVAS (G.)
MARDONES (E.)
Chile

REALIZACIÓN DE LA ELECTRIFICACIÓN RURAL EN CHILE, POR MEDIO DE COOPERATIVAS ELÉCTRICAS

Por Tec. GUSTAVO CUEVAS
y Ing. ENRIQUE MARDONES
COMITÉ NACIONAL CHILENO

La Empresa Nacional de Electricidad S. A. (ENDESA), subsidiaria de la Corporación de Fomento de la Producción de Chile, tiene como objetivo principal la realización del Plan de Electrificación del País. Dicho Plan contempla, además de la instalación de centrales eléctricas y sus correspondientes líneas de transmisión y subestaciones para hacer llegar la energía a los centros de consumo, la electrificación de los predios agrícolas.

COOPERATIVAS DE CONSUMIDORES

El suministro de energía eléctrica a los consumidores agrícolas se ha desarrollado principalmente por medio de la formación de cooperativas de consumidores rurales, pues se ha llegado a la conclusión de que esta forma de organización constituye el medio más económico para hacer llegar la energía eléctrica a las faenas de la agricultura.

En las cooperativas de electrificación rural, los cooperados son dueños de las instalaciones, administradores de la organización a través de su consejo directivo y consumidores de la energía eléctrica que adquieren de la ENDESA y que ellos mismos distribuyen. En esta forma los miembros de las cooperativas obtienen el beneficio de una administración económica, pues no es el objetivo de las cooperativas obtener utilidades en el negocio, sino solamente poner a disposición de sus socios la energía eléctrica necesaria para las labores agrícolas.

La ENDESA vende la energía eléctrica directamente a las cooperativas en las subestaciones que ha construido a lo largo del país. Normalmente la energía es entregada en estas subestaciones al voltaje de

13.200 V., siendo de cargo de las cooperativas las inversiones correspon- [illegible] sub-estaciones de distribución para atender a los consumos. Los capitales necesarios son aportados por los socios a las cooperativas exclusivamente para la construcción de estas obras, quedando a cargo de la ENDESA las inversiones necesarias para la generación y distribución primaria.

Para la formación de las cooperativas rurales de electrificación la ENDESA se encarga no sólo de su organización legal como entidades autónomas, sino también de confeccionar los proyectos y realizar la construcción de las líneas y sub-estaciones de distribución. Los proyectos se realizan teniendo en consideración, además del servicio de los cooperados, los posibles nuevos consumos que puedan desarrollarse en la zona abarcada por la cooperativa. Para el estudio y realización de estos proyectos, ENDESA dispone de personal especializado y equipos de construcción adecuados. Los proyectos son confeccionados de acuerdo con las normas y planos tipos desarrollados conforme con la experiencia adquirida por ENDESA en este tipo de construcciones, lo que se traduce en economía en las instalaciones y bajos costos de explotación.

La ayuda que la ENDESA presta a las cooperativas para su organización, para los proyectos y para la construcción de las instalaciones, se complementa tambien con ayuda financiera. Esta consiste en el otorgamiento de préstamos a bajo interés, a 2 ó 3 años de plazo, que cubren el 10% de la cuota asignada a cada cooperado.

Una vez terminada la construcción de las obras, la cooperativa se hace cargo de su explotación. La mantención de las líneas y sub-estaciones es efectuada, en general, por la ENDESA, por cuenta de las cooperativas.

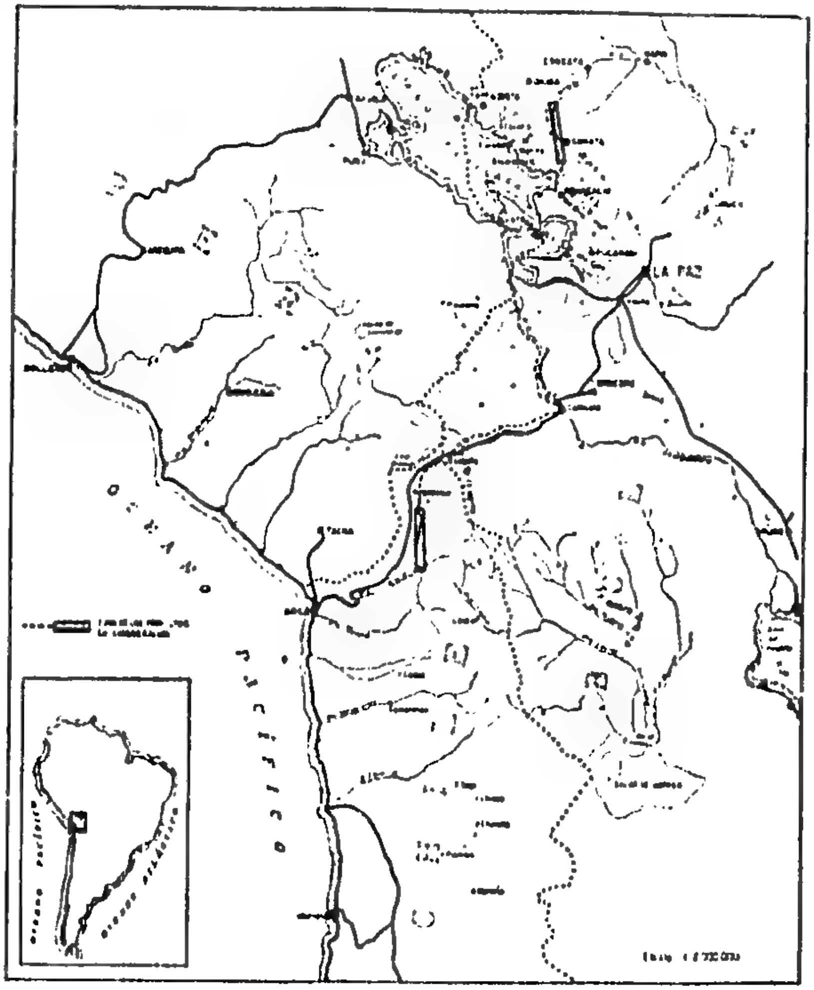
Se encarga tambien la ENDESA de proporcionar a las cooperativas normas de caracter técnico y administrativo, para su mejor funcionamiento. Los estatutos de las cooperativas tienen cláusulas mediante las cuales ENDESA mantiene supervisión técnica y financiera, pudiendo tomar las medidas necesarias tendientes a contribuir a su mejor marcha.

Las cooperativas reciben suministro eléctrico permanente de la ENDESA y sus socios pueden utilizar la energía eléctrica en toda clase de instalaciones, sea de carácter doméstico, agrícola o industrial, incluyendo por cierto el regadío de los campos por medio de bombas eléctricas.

OBRAS REALIZADAS POR LA ENDESA

Inmediatamente que entró en servicio la central hidroeléctrica Pilmaiquén, a fines de 1944, se inició la electrificación de las zonas rurales correspondientes a la zona servida por esta central. Posteriormente, y a partir de 1948, con la puesta en servicio de las centrales Sauzal y Abanico, la electrificación rural se extendió también a la zona abastecida por estas últimas.

Hoy día se encuentran en explotación 9 cooperativas de electrificación [illegible] sistemas hidroeléctricos. En efecto, en el sistema Pilmaiquén están en operación las cooperativas de Osorno, Río Bueno-Ranco, Llanquihue y Paillaco. En el sistema Abanico, las coope-



rativas de Chillán, Monte Aguila-Cabrero y Yumbel; y en el sistema Sauzal, las cooperativas de Talca y Curicó.

Estas cooperativas explotan hoy día 1.468 Km. de líneas de distribución a 13.200 V. y cuentan con 1.262 socios consumidores, o sea tienen una densidad de 1,16 Km. de línea de 13.200 V. por predio electrificado.

En el cuadro que sigue se muestran los índices principales correspondientes a estas 9 cooperativas.

COOPERATIVAS DE ELECTRIFICACION RURAL EN FUNCIONAMIENTO

([illegible] calculadas para el año terminado en el mes de Octubre de 1953)

Nombre de la cooperativa	*Año en que inició el servicio*	*Número de predios electrificados*	*Longitud de línea de 13.200 V. por predio Km.*	*Consumo medio mensual por consumidor (1) KWH*
Osorno	1945	450	1,20	441
Río Bueno-Ranco ...	1948	161	0,81	186
Llanquihue	1949	86	1,39	316
Paillaco	1949	70	1,00	132
Chillán	1951	135	1,41	241
Monte Aguila-Cabrero	1951	40	1,17	134
Yumbel	1953	27	1,89	399
Talca	1950	223	1,10	426
Curicó	1951	67	0,79	380

(1) Corresponde al consumo de 12 meses.

INDICES ANUALES DE LA COOPERATIVA RURAL ELECTRICA DE OSORNO

(Las cifras de 1953 han sido estimadas para el último bimestre)

Año	*Número de predios electrificados*	*Longitud de línea de 13.200 V. por predio Km.*	*Consumo medio mensual por consumidor KWH*
1945	65	1,08	103
1946	115	1,21	122
1947	207	1,01	142
1948	225	1,15	275
1949	251	1,26	315
1950	310	1,15	316
1951	429	1,16	333
1952	431	1,21	400
1953	455	1,20	456

Además de las cooperativas mencionadas, actualmente se encuentran en formación y con parte de sus redes construídas o en proyecto, 6 nuevas cooperativas y se está en organización de 5 más, en forma que a corto plazo existirán unas 20 cooperativas de electrificación rural en funcionamiento en Chile.

Como un índice de la capacidad de consumo de energía eléctrica en la agricultura, en el estado actual de desarrollo de Chile, se señalan las cifras correspondientes a la cooperativa de Osorno, que fué la primera que se organizó.

Al realizar la ENDESA la distribución de energía eléctrica en las zonas rurales del país en la forma indicada y en estrecha coordinación con la realización del plan de construcción de centrales hidroeléctricas, líneas y sub-estaciones primarias, está cumpliendo con las directivas del Plan de Electrificación de Chile, en el sentido de fomentar la producción por medio de la mecanización de las faenas agrícolas. Esto ha permitido aumentar el rendimiento del trabajo y proporcionar a aquellos que viven en los campos un nivel de vida equivalente a aquellos que viven en los pueblos y ciudades, contribuyendo así a suprimir uno de los factores que influyen en la emigración de la población agrícola a los centros urbanos.

La obra realizada por la ENDESA en cortos años y que ha permitido proporcionar energía a 1.262 consumidores agrícolas, es sólo una pequeña parte del programa de electrificación rural. En efecto, es el propósito de ENDESA avanzar con líneas de electrificación rural hasta cubrir todas las zonas agrícolas de Chile, en forma de aumentar el rendimiento agrícola del país y proporcionar en las zonas adecuadas el regadío mecánico, mediante la elevación de agua por medio de bombas accionadas por motores eléctricos, cumpliendo así uno de los propósitos de incremento de la producción agrícola, que forma parte de los planes de la Corporación de Fomento de la Producción.

RESUMEN

Los autores exponen que el suministro de energía eléctrica a los predios agrícolas forma parte del Plan de electrificación de Chile. Esto se ha desarrollado por medio de cooperativas de consumidores rurales. Los cooperados son dueños de las instalaciones, administradores y consumidores de la energía eléctrica que adquieren y distribuyen.

La energía eléctrica la obtienen de la Empresa Nacional de Electricidad S. A. (ENDESA), siendo de cargo de las cooperativas las líneas y sub-estaciones de distribución a sus miembros. La formación de las cooperativas, la construcción y la mantención de las instalaciones son efectuadas por la ENDESA, por cuenta de los cooperados, a quienes también ayuda financieramente mediante préstamos.

Las obras realizadas por la ENDESA, desde 1941 a 1953, corresponden a 9 cooperativas distribuidas en los diferentes Sistemas Eléctricos Regio-

[illegible] 1.168 Km. de líneas de distribución a 13.200 V. y cuentan con 1.262 socios consumidores, correspondiendo en promedio [illegible] predio electrificado.

Como índice de la capacidad de consumo de energía eléctrica en la agricultura chilena, se señalan las cifras de la primera cooperativa organizada, la de Osorno, con aumento de 65 à 455 predios electrificados y consumos medios mensuales de 103 à 456 KWH, en el período de 1945 hasta Octubre de 1953.

El objetivo de la electrificación rural es fomentar la producción por medio de la mecanización de las faenas agrícolas, aumentando el rendimiento del trabajo y mejorando el nivel de vida de los que viven en los campos. Sólo se ha hecho una pequeña parte y la ENDESA tiene el propósito de cubrir con las líneas de electrificación rural todas las zonas agrícolas de Chile, con inclusión del regadío mecánico, con elevación de agua con bombas eléctricas, en aquellas zonas que lo necesitan.

Résumé

Les auteurs exposent que le fournissement d'énergie électrique à la campagne est une part du Plan d'Electrification du Chili. Cette part a été developpée par le moyen de cooperatives de consommateurs ruraux. Les coopérés son propriétaires des installations, administrateurs et consommateurs de l'énergie électrique qu'ils achètent et distribuent.

L'énergie électrique est obtenue de l'Empresa Nacional de Electricidad S. A. (ENDESA) étant à charge aux cooperatives, les réseaux et sous-stations de distribution à se membres. L'organisation des cooperatives, la construction et manutention des installations sont effectuées par ENDESA, a charge aux cooperatives, auxquelles elle donne aussi de l'aide au moyen d'emprunts.

Les oeuvres faites par ENDESA depuis 1941 jusqu'à 1953, correspondent à 9 cooperatives distribués dans les différents Systèmes Régionaux. Ils ont, en total, 1.168 Km. de réseaux de distribution à 13.200 V. et 1.262 consommateurs associés, avec un indice moyen de 1,16 Km. par proprieté électrifiée.

Comme indice de la capacité de consommation d'énergie électrique dans l'agriculture au Chili, on donne les chiffres de la première coopérative organisée, celle d'Osorno, avec une augmentation de la consommation moyenne mensuelle de 103 à 456 KWH, dans la période comprise entre 1945 et Octobre de 1953.

L'objetif de l'électrification rurale est de développer la production au moyen de la mécanisation des travaux agricoles, en augmentant le rendement du travail et en élevant le niveau de vie de ceux qui vivent à la campagne. On a fait seulement une petite part et ENDESA a le propos d'étendre ses réseaux d'électrification rurale à toutes les zones

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agricoles du Chili, et d'équiper l'irrigation mécanique avec élévation de l'eau au moyen de pompes électriques, dans les régions où ça soit nécessaire.

SUMMARY

The authors express that the power supply to the farms is a part of the Electrification Plan of Chile. This has been developed through rural electrification cooperatives. The members of the cooperatives are the owners of the installations, managers, and consumers of the electric power that they buy and distribute.

The "Empresa Nacional de Electricidad S. A." (ENDESA) supplies the power and the cooperatives run the distribution lines and sub-stations. The creation of the cooperatives, the construction of the installations and their maintenance is done by the ENDESA, on account of the cooperatives. ENDESA also gives financial help through granting loane to their members. Since 1944, ENDESA has developed 9 cooperatives located in different electric systems. They have now 1,468 Km. of distribution lines at a voltage of 13,200 V. and they have 1,262 consumer members, that is, 1,16 Km. per consuming electrified farm.

As an index of the electric consuming capacity of the Chilean agriculture the authors show some figures of the first organized cooperative, "Osorno", with an increase from 65 to 455 electrified farms and an average annual consumption from 103 to 456 KWH in the period since 1945 to October 1953.

The main object of the rural electrification is to develop the production by means of the electrification of the agricultural labors, increasing their efficiency and the standard of living of those who live in the rural areas. Only a small part of the task has been done as ENDESA has the purpose of covering with rural electrification lines all agricultural zones of Chile, including the supply of power for mechanical irrigation by means of electric pumps, to the areas where this kind of irrigation is required.

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CONFERÊNCIA MUNDIAL DA ENERGIA
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REUNIÃO PARCIAL
SECTIONAL MEETING
Rio de Janeiro — 1954

Assunto 2.1.2

KRAETZER (M. H.)
Suiça

PROBLÈME D'APPLICATION DES MOTEURS DIESEL SOUS DIFFÉRENTS ASPECTS TECHNIQUES

Par Ing. M. H. KRAETZER

COMITÉ NATIONAL SUISSE

INTRODUCTION

L'énergie électrique s'étant révélée au cours des dernières décades un élément important dans le développement des peuples, on a été conduit à pousser à fond l'étude des problèmes de la production d'électricité. Aujourd'hui, la création de centrales électriques a été maintes fois discutée, étudiée et exposée et la principale question est de faire un choix parmi les différents systèmes à disposition. L'énergie de base est dans certains cas donnée par les ressources naturelles d'énergie du pays. Là où cette énergie fait défaut, il faut l'importer sous une forme ou sous une autre. Nous nous proposons de faire ressortir les différents facteurs parlant en faveur du moteur Diesel dans l'installation de centrales électriques. Nous décrirons brièvement les particularités des centrales hydrauliques, puis attaquerons le problème des centrales thermiques Diesel en examinant les cas où elles s'imposent. La fin de notre exposé sera consacrée à un examen de la situation de l'énergie électrique au Brésil.

LES CENTRALES HYDRO-ÉLECTRIQUES

Il est nécessaire que nous rappelions en quelques mots les particularités de ces centrales afin de permettre une comparaison plus aisée avec les centrales thermiques et spécialement les centrales Diesel.

Au point de vue exploitation et frais d'établissement, les centrales hydro-électriques diffèrent sensiblement des centrales thermiques. Les premières exigent en général un gros capital d'établissement. Ce capital est 4 à 5 fois plus élevé que celui nécessaire à la construction d'une centrale

thermique de même puissance. L'usine ne pouvant être placée ailleurs [illegible] est disponible, l'énergie produite doit être souvent transportée jusqu'au centre de consommation. Une fois terminée, l'exploitation n'entraine que peu de frais de personnel et d'entretien. L'intérêt et l'amortissement du capital engagé pour le barrage, la conduite forcée pour autant que celle-ci soit nécessaire, la centrale, le poste élévateur de tension et les lignes de transport de l'energie jusqu'au centre de distribution constituent la majeure partie des charges. Ces frais sont pratiquement constants quelque soit l'utilisation de la centrale.

La puissance disponible dépend de nombreux facteurs. Les conditions météorologiques et les précipitations influent sur le *régime* des eaux; les saisons et les années sèches sont des facteurs dont il faut tenir compte lors de l'établissement du projet de ces centrales. Les variations de production qui s'ensuivent sont loin de correspondre à la demande d'énergie telle que nous la connaissons en Suisse par exemple, avec les pointes en fin de matinée et la forte demande de courant de chauffage et d'éclairage en hiver.

Outre les questions de production et de frais d'installation, les centrales hydrauliques, parce qu'elles comportent d'importants travaux de génie civil, présentent l'inconvénient d'une longue durée de construction. Il faut compter actuellement avec 5 à 8 ans, alors qu'une centrale thermique de même puissance peut être réalisée en 2 à 3 ans. Enfin, l'érection d'une centrale hydraulique exige souvent de longues négociations pour l'obtention des concessions requises.

LES CENTRALES THERMIQUES

Elles ont l'avantage de pouvoir être installées sinon au lieu même de la consommation, tout au moins à proximité immediate. Elles peuvent livrer l'énergie directement à la tension de distribution ou à celle de consommation et ne nécessitent pas de longues et onéreuses conduites de transmission. Les frais d'installation sont beaucoup moins élevés, mais par contre les frais d'exploitation résultant de l'achat du combustible viennent s'y ajouter. Toutefois ces frais sont plus ou moins proportionnels à l'énergie effectivement debitée.

La construction des centrales thermiques n'est généralement assujettie à aucune demande de concession et elle exige une surface de terrain minimum.

La durée relativement courte de construction, la possibilité, et facilité d'agrandissement d'une part, l'avantage d'une mise en marche très rapide et la flexibilité dans la production de l'énergie font de la centrale Diesel un instrument très apprécié, même dans les pays où les forces hydrauliques sont très developpées, comme la Suisse par exemple.

Les frais de production de l'energie par kWh au moyen de moteurs de moyenne et de petite puissance ne sont relativement pas beaucoup

plus élevés que ceux des grandes centrales, par suite de l'augmentation peu importante des frais d'établissement et du fait que le rendement est très élevé et à peu de chose près le même pour toutes les puissances.

Pour une centrale à vapeur, il faut disposer d'eau de réfrigération en quantité suffisante et c'est là souvent une suggestion importante. Le Diesel ne nécessite que relativement peu d'eau ou même point du tout si l'on a recours à des réfrigérant-radiateurs. A cet avantage s'ajoute celui du rendement qui n'est nullement affecté par la température de l'eau utilisée pour son refroidissement.

En ce qui concerne la turbine à gaz, l'eau de réfrigération et sa température jouent aussi un rôle prépondérant dans le cas d'une installation à haut rendement thermique nécessitant des réfrigérants intermédiaires dans la compression de l'air comburant.

Même en Suisse, le pays classique des forces hydrauliques, la centrale thermique Diesel a été introduite en liaison avec des réseaux de distribution d'énergie hydro-électrique déjà dans un temps où une grande partie des forces naturelles étaient encore disponibles. La présence d'une centrale thermique dans un centre de consommation permet une meilleure utilisation de l'énergie hydraulique, tout en la régularisant. Le rôle de régularisateur est spécialement imputable au Diesel qui, du fait de sa souplesse, permet une utilisation complète de l'énergie hydraulique. En même temps, une usine Diesel peut servir de réserve ou de secours instantané lors de perturbations dans les lignes de transport de l'énergie d'origine hydraulique.

A côté des usines alimentant des distributions publiques, il y a place pour des centrales alimentant individuellement des industries diverses. Ces centrales sont particulièrement intéressantes pour les entreprises privées d'une certaine importance. L'avantage de la mise en marche très rapide et celui de pouvoir travailler à pleine charge en quelques minutes, rendent le Diesel aussi intéressant pour certaines entreprises publiques, telles que hôpitaux, administrations etc. où ils servent alors de groupes de secours.

Le champ d'application du moteur Diesel dans le domaine de la production d'énergie est donc très vaste et dans bien des cas, il est plus avantageux et mieux adapté que les turbines hydrauliques, à vapeur ou à gaz. Toutefois, il convient de relever que les avantages qu'il offre ne peuvent pas être mis à profit d'une manière illimitée, car la puissance par unité ne dépasse guère 11 à 15.000 CV. Il s'ensuit que pour des grandes puissances, le Diesel est moins intéressant et ne peut entrer en concurrence avec la turbine à vapeur et la turbine à gaz, qui occupent moins de terrain par unité de puissance et accusent un meilleur rendement que de petites unités. Cependant, dans certaines conditions, comme par exemple l'absence d'eau, de grandes centrales Diesel, voire celle de Broken Hill en Australie, ont été créées. Cette centrale se compose de deux usines, d'une puissance totale d'env. 50.000 CV; la figure 1 donne une vue de la seconde, qui est de construction plus récente.

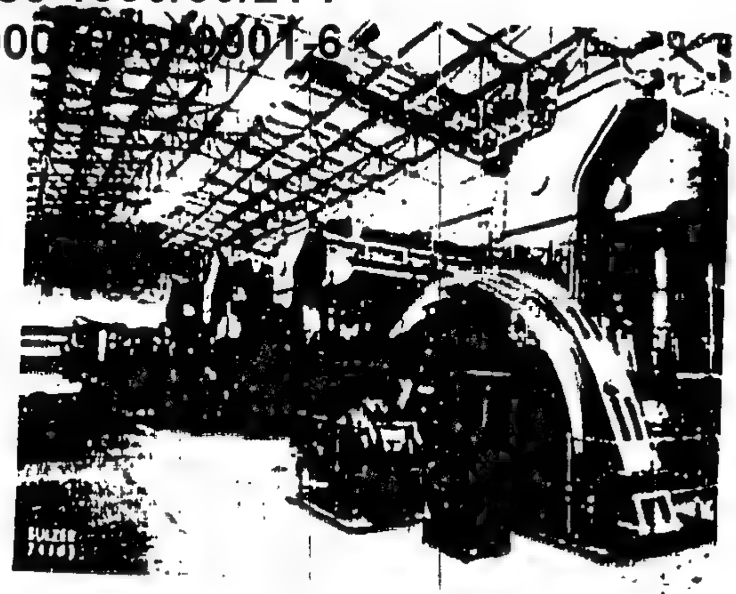

Fig. 1 -- Centrale de Broken Hill

COMMENT SE POSE LE PROBLÈME AU BRÉSIL.

Avant d'envisager la solution du problème technique au Brésil, il y a lieu tout d'abord d'étudier les conditions géographiques, industrielles et climatériques régnant actuellement dans ce pays.

Du point de vue géographique, on peut partager très grossièrement le pays en deux parties principales: Fig. 2

a) Le bassin de l'Amazone et de ses affluents couvrent les 3/4 du pays (région tropicale)

b) Les régions côtières de l'Est.

Cette séparation correspond exactement à celles que nous pourrions faire en prenant la carte industrielle du pays. Les industries sont presques toutes concentrées dans les régions côtières où se trouve également la majorité des habitants, c'est-à-dire des consommateurs.

Il y a donc deux problèmes différents ayant trait à deux régions:

1) Un problème de développement technique dans les régions côtières industrielles, perfectionnement et agrandissement, modernisation des installations existantes.

2) Une problème de pénétration avec création de sources d'énergie où celles-ci manquent totalement, c'est-à-dire dans la région intérieure.

... la répartition des centrales électriques est à peu près la suivante :

Les régions côtières industrielles sont équipées presque exclusivement de centrales hydrauliques et ceci principalement dans la partie Sud de la côte. La puissance totale des installations hydrauliques s'élève à 1.585.000 kW. A cette puissance viendra s'ajouter dorénavant l'énergie exploitée du Rio São Francisco dans le Nord. La côte Nord-Est, la partie au Nord de l'Etat de Bahia, le bassin de l'Amazone et l'intérieur du pays sont équipés uniquement de centrales thermiques. La puissance totale des installations thermiques atteint 355.000 kW.

D'autre part, il existe au Brésil un très grand nombre de petits groupes électrogènes privés de 20 à 50 kW qui ne sont rattachés à aucun réseau de distribution.

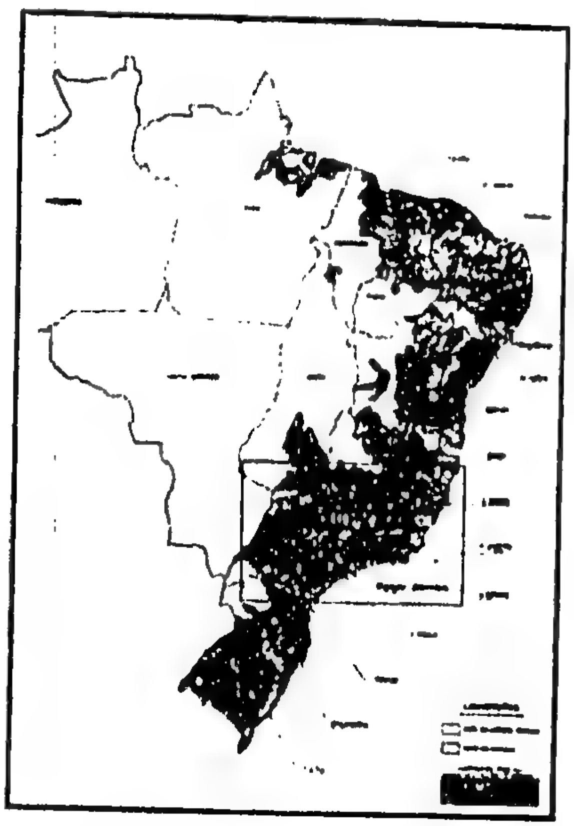

Fig. 2 — Carte du Brésil

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Les arguments en faveur des centrales Diesel ne perdent rien de leur valeur pour le Brésil, ils y sont même fortement accentués. Dans un pays où le combustible doit être importé, il est essentiel pour l'économie publique de veiller à un usage aussi rationnel que possible de cette source d'énergie; on donnera la préférence (toutes autres conditions étant égales) à la machine ayant le plus haut rendement, c'est-à-dire au Diesel. Il est vrai qu'il y a lieu d'ajouter à la consommation en combustible du Diesel sa consommation en lubrifiant; mais même en tenant compte des dépenses pour l'huile de graissage, le Diesel l'emporte sur l'installation à vapeur et la turbine à gaz. Cette dernière est d'ailleurs très sensible aux conditions climatériques du lieu de l'installation, étant donné que sa puissance comme son rendement sont fortement influencés par la température de l'air comburant et de l'eau de refroidissement. Ce dernier point joue un grand rôle pour le Brésil, pays tropical.

En ce qui concerne les régions intérieures, la situation est la suivante:

Si l'on considère le pourcentage de la puissance installée thermique de 22,4 % (à la fin de 1952), représentant 335.000 kW, installés et répartis exclusivement dans une région qui couvre environ les 1/3 de la superficie du pays, on aura ainsi une preuve de plus des avantages que présente le groupe Diesel électrique pour les régions en plein développement. La petite ville isolée, loin de toute centrale électrique, disposera de deux groupes au minimum. L'agrandissement toujours possible se fera très facilement grâce à la simplicité de l'installation Diesel.

La centrale de Campina Grande comporte deux moteurs de 900 CV, auxquels viendra s'ajouter un troisième. Située dans le Nord du Brésil, elle alimente la ville en électricité pour la lumière et fournit en même temps l'énergie électrique nécessaire aux diverses industries de la ville (figure 3).

Le moteur Diesel est certainement la machine la plus appropriée pour l'équipement des régions non encore électrifiées. Chaque municipalité ou district peut acquérir dans le but de développer l'artisanat, les industries locales, l'hygiène publique et les conditions sociales, un ou deux groupes Diesel électriques. Ce district ne disposant généralement pas des moyens nécessaires à l'installation d'une centrale hydraulique de moyenne puissance, la centrale Diesel au capital d'établissement minimum et dont la mise en service pourra avoir lieu très rapidement, offrira la meilleure solution au point de vue économique.

Beaucoup de pays sont d'ailleurs dans la même situation que le Brésil et ont utilisé le Diesel pour les mêmes conditions, comme par exemple:

La centrale Diesel électrique de Cali en Colombie, comportant quatre moteurs Diesel à deux temps de 2 400 CV chacun. Elle livre du courant à la tension de 2400 Volts, tension qui est élevée par le transformateur à 13.200 Volts. L'usine marche en parallèle avec plusieurs centrales hydrauliques de la région de Cali, ainsi qu'avec une autre centrale Diesel (figure 1

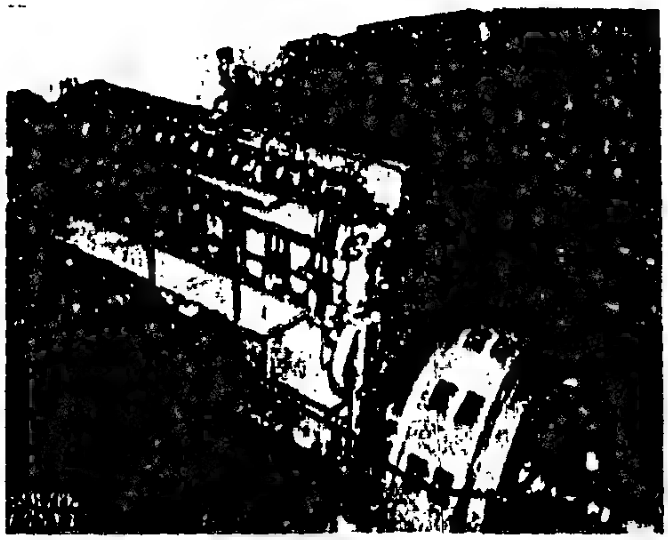

Fig. 3 — Centrale de Campina Grande

Enfin, il y a lieu de relever que la chaleur perdue dans l'eau de refroidissement et les gaz d'échappement peut être récupérée pour la production d'eau chaude, ce qui augmente le rendement global de l'installation et lui assure une exploitation rationnelle et économique. Ceci est particulièrement intéressant pour des abattoirs, hôpitaux, hôtels, brasseries, laiteries, etc.

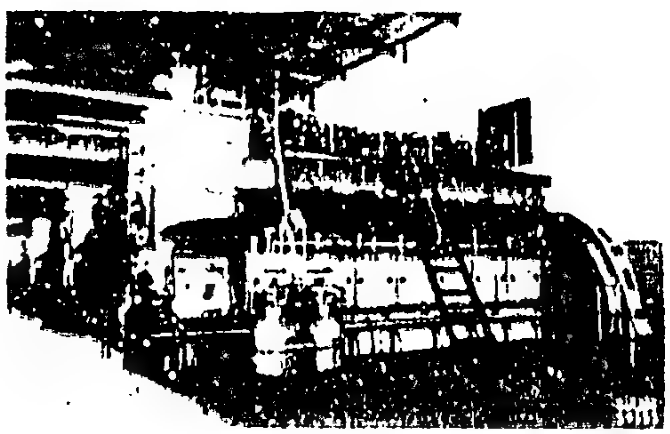

Fig. 4 — Centrale de Cali

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[illegible] la centrale de Felsenau en Suisse, comportant un moteur 600 CV [illegible] montre au fond le récupérateur de chaleur [illegible] et l'accumulateur de chaleur au milieu

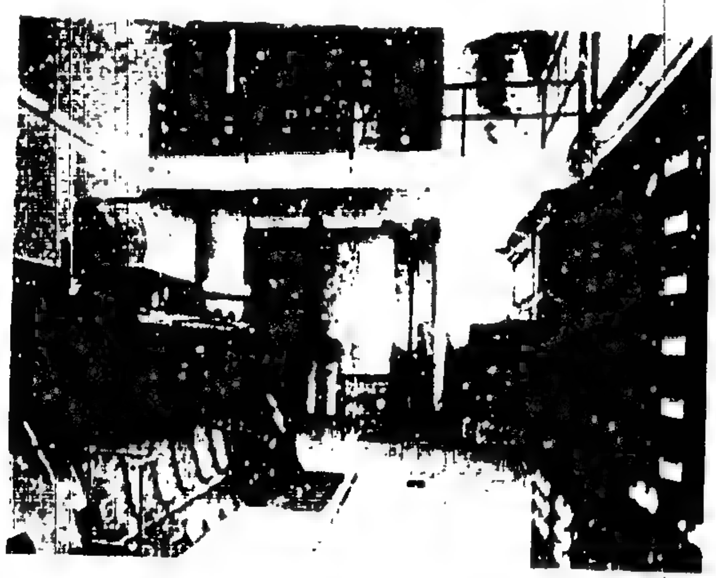

Fig. 5 — Felsenau

RÉGIONS INDUSTRIELLES

Ces régions sont alimentées par de grandes centrales. Du point de vue consommation d'énergie, le Brésil présente une particularité. Une comparaison entre des diagrammes journaliers brésiliens et suisses par exemple (figure 6,7) met en évidence une différence très marquée, ce qui influence le choix des moyens de production d'énergie. Par ailleurs, il existe encore au Brésil deux fréquences 50 et 60 pour le courant triphasé et en plus le courant continu, ce qui s'oppose, pour le moment, à l'interconnexion des réseaux.

Il nous semble toutefois important de relever les avantages qu'offre l'interconnexion des réseaux hydrauliques entre eux d'une part et avec des centrales thermiques d'autre part, car plus une zone de consommation est étendue, moins la puissance absorbée est variable; il en résulte à la fois une économie d'exploitation. Remarquons d'ailleurs qu'un projet d'interconnexions partielles a été élaboré. Toutefois, ceci ne suffira probablement pas encore pour garantir l'utilisation rationnelle des forces hydrauliques.

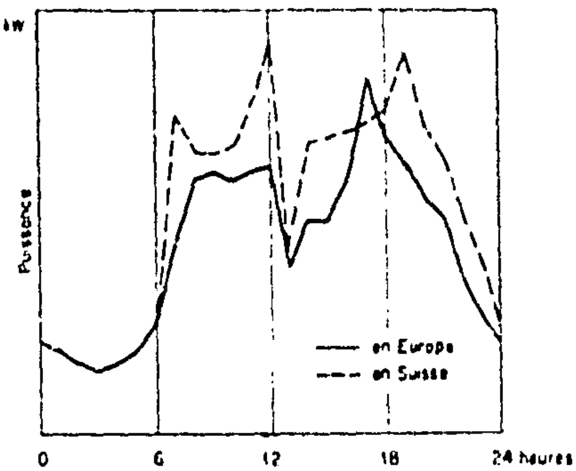

Fig. 6 — Allure générale d'un diagramme de charge journalier en Europe et en Suisse

Les liaisons entre les centres de production hydrauliques et les centres de production thermiques, qui sont en même temps les centres de grandes consommations, permettent de mieux absorber encore l'énergie hydraulique produite, tout en la régularisant. En même temps, ces usines thermiques jouent le rôle de réserves ou de secours instantanés susceptibles de parer notamment à un accident survenant sur la ligne de transport d'énergie hydraulique. L'interconnexion d'usines thermiques avec les usines hydrauliques qui se trouvent dans le voisinage, est certainement indiquée dans un pays où l'interconnexion des usines hydrauliques des différentes régions du pays devient onéreuse à cause des grandes distances qu'il faut franchir avec des lignes aériennes.

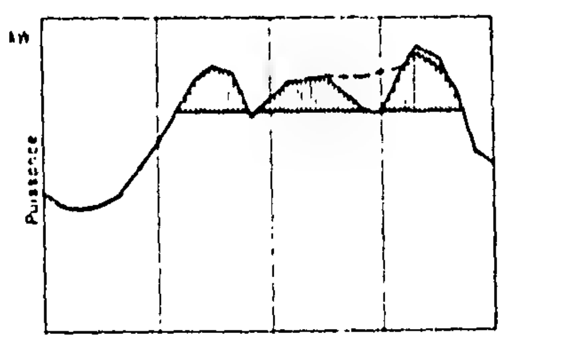

Fig. 7 — Allure générale d'un diagramme de charge journalier au Brésil

[illegible] centrales Diesel avec les réseaux n'est pas accep[illegible] que le moteur Diesel ne peut être considéré dans la région industrielle, du moins pour le moment, que comme groupe de secours en cas de perturbation dans la ligne de distribution.

Ceci est particulièrement intéressant, comme nous l'avons déjà fait ressortir, pour des hôpitaux, hôtels etc. La figure 1 montre une telle installation dans laquelle le moteur est installé sur des fondations élastiques empêchant la transmission de vibrations au bâtiment. Par ailleurs, dans cette catégorie d'installations toutes les précautions sont prises pour empêcher la transmission des bruits aux locaux habités (figure 8).

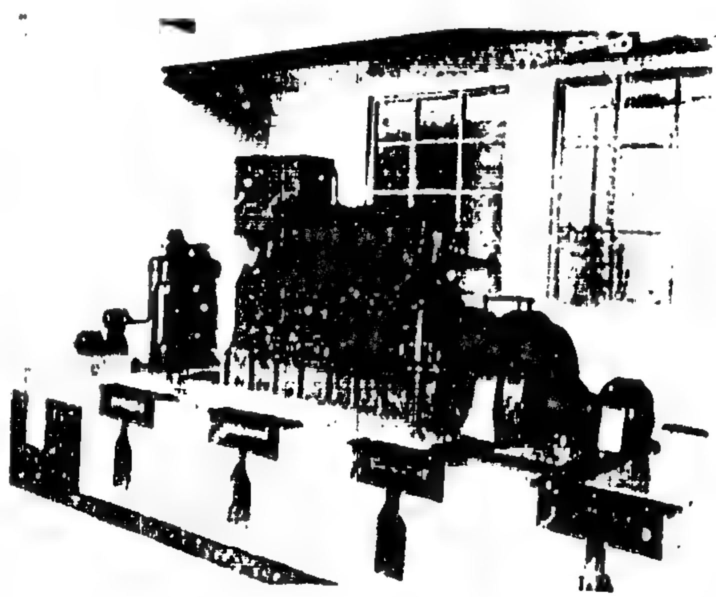

Fig. 8 — Moteur à quatre temps sur fondation élastique

Résumé

Le rapport donne une comparaison d'ordre général entre les caractéristiques des centrales hydro-électriques et thermiques et pour ces dernières plus spécialement des centrales équipées de moteur Diesel. Il examine ensuite les conditions particulières qui se présentent au Brésil et relève les avantages que peut offrir le moteur Diesel pour l'équipement des régions encore non électrifiées d'une part et en connexion avec les réseaux existants d'autre part.

Summary

The paper gives a general survey of the characteristics of hydroelectric and thermal power plants and especially Diesel power plants. The specific conditions prevailing in Brazil are then analysed and the advantages of the Diesel power plant put forward with respect to the equipment of not yet electrified regions on one hand and in connection with existing grids on the other hand.

Resumo

Preliminarmente são dadas, no presente trabalho, as características principais de centrais hidro e termo-elétricas e destas últimas particularmente as das Diesel-elétricas. A seguir são analisadas as condições especiais existentes no Brasil, fazendo-se ressaltar as vantagens oferecidas pelos grupos Diesel-elétricos, tanto para regiões ainda não eletrificadas como para o uso em paralelo com sistemas elétricos já existentes.

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REUNIÃO PARCIAL
SECTIONAL MEETING
Rio de Janeiro — 1954

WEBER (M. H.)
Suisse

TURBINES À GAZ EXPLOITÉES EN AMÉRIQUE DU SUD

Par M. HANS WEBER

COMITÉ NATIONAL SUISSE

INTRODUCTION

Au point de vue de la production d'énergie, l'année 1949 présente, pour l'Amérique du Sud, un intérêt historique. En cette année, en effet, on y a mis en service les premières installations à turbines à gaz. C'était sans doute, à cette époque, un certain risque d'opter pour la turbine à gaz, car les expériences acquises avec les grandes installations de ce genre n'étaient guère nombreuses. Certes, on avait déjà alors, en plus des résultats de recherches de laboratoire, l'expérience acquise au cours de l'exploitation des premières turbines à gaz industrielles installées en Europe.

C'est principalement à cette expérience que l'on doit la grande sécurité de marche déjà atteinte par les premières installations à turbines à gaz d'Amérique du Sud. Grâce à elles également, on a pu remédier définitivement et en un minimum de temps aux quelques difficultés survenues au début de leur exploitation.

Aujourd'hui on dispose des enseignements recueillis au cours de longues années d'exploitation de plusieurs installations à turbine à gaz, travaillant dans les conditions les plus diverses. C'est avant tout ces résultats de marche en service continu d'installation industrielles qui, au mieux, renseignent l'ingénieur d'exploitation et lui permettent de se faire une opinion sûre quant aux possibilités et à la sécurité de marche d'un nouveau type de machine.

Dans ce qui suit, nous aimerions décrire succinctement les trois premières installations à turbines à gaz d'Amérique du Sud ainsi que les expériences acquises au cours de leur exploitation.

Chimbote

La première installation à turbine à gaz mise en service en Amérique du Sud fut celle de Chimbote, localité du Pérou, à 400 km au nord de Lima. Un grand centre sidérurgique est là-bas en construction qui, en temps normal, recevra son énergie d'une usine hydroélectrique nouvellement construite. Une turbine à gaz de 1000 kW a été prévue comme installation de réserve. On a choisi l'exécution la plus simple, à cycle

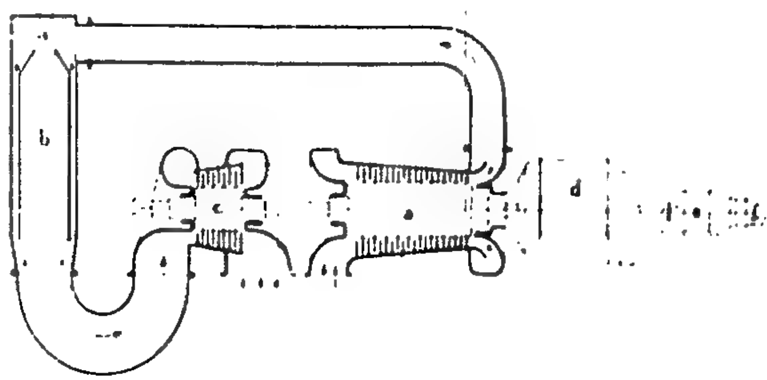

Fig. 1 — Schéma de l'installation à turbine à gaz de Chimbote

a — Compresseur; b — Chambre de combustion; c — Turbine à gaz;
d — Alternateur triphasé; e — Moteur de lancement; f — Excitatrice

ouvert, sans aucun récupérateur de chaleur. On renonçait ainsi délibérément à un rendement élevé; en revanche, on s'assurait une exécution extraordinairement simple et peu coûteuse, de service et d'entretien très aisés.

La fig. 1 représente le schéma de cette installation. L'air est aspiré à travers un filtre rotatif imprégné d'huile. Le combustible employé est de l'huile Diesel. L'installation est cependant prévue pour être, à volonté, transformée pour la marche au gaz de hauts fourneaux. Le refroidissement de l'huile de graissage et de l'air de ventilation de l'alternateur se fait à l'eau. La consommation d'eau est de 60 m³/h environ. Il serait

... complètement de ... Actuellement ... à gaz sont en construction pour les ... de graissage ne sont refroidis qu'à l'air.

Les caractéristiques essentielles ressortent du tableau I.

TABLEAU I

CARACTÉRISTIQUES TECHNIQUES DE LA TURBINE À GAZ DE CHIMBOTE

Puissance aux bornes de l'alternateur	4000 kW
Vitesse de rotation	3000 t/min
Quantité d'air	51 kg/s
Température de l'air aspiré	20 °C
Température à l'entrée de la turbine	580 °C
Rapport de compression	3,6
Rendement combustible-bornes	18 %

L'installation de Chimbote fut mise en service en 1949. Du fait d'un retard dans la construction de l'usine sidérurgique, elle n'a fonctionné jusqu'ici qu'à charge partielle, le plus souvent entre 300 et 500 kW seulement. Elle n'a de ce fait à son actif, qu'un peu plus de 5000 heures de service. Mise à part la rupture d'une aube du compresseur, cette installation a donné entière satisfaction (fig. 2).

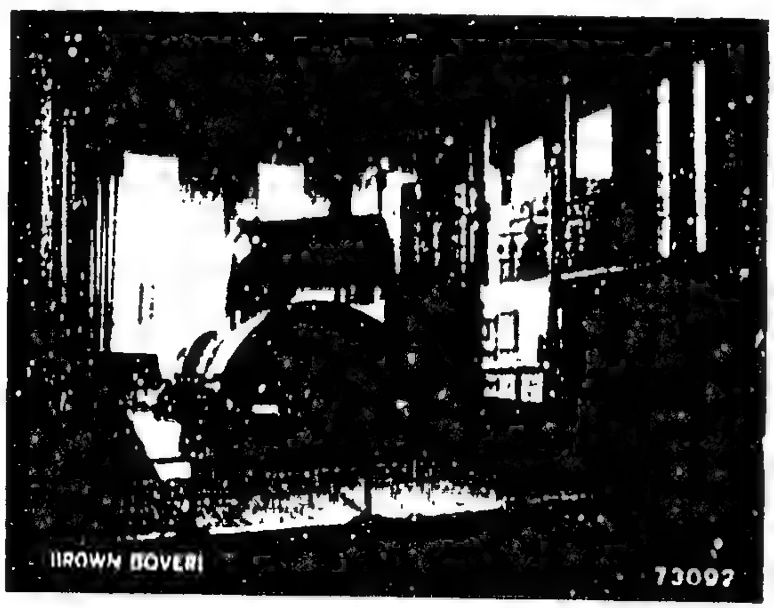

Fig. 2 — Vue générale de l'installation à turbine à gaz de Chimbote.

Lima

En novembre 1949, à Lima, la première turbine à gaz à plusieurs lignes d'arbres d'Amérique du Sud fut mise en service. Cette installation est située à proximité immédiate de la ville et elle alimente en parallèle avec d'autres usines thermiques et hydro-électriques le réseau de la capitale péruvienne. Sa puissance est de 10000 kW.

L'installation, dont la disposition ressort de la fig. 3, comprend deux groupes de machines, un groupe à haute pression et un groupe à basse pression. L'alternateur est entraîné par le groupe à haute pression. L'air est comprimé en trois étages entre lesquels il est refroidi par des réfrigérants à eau. Les gaz de combustion se détendent dans une première turbine puis sont réchauffés dans la chambre de combustion basse-pression pour passer ensuite dans la seconde turbine. L'installation de Lima comprend encore un récupérateur de chaleur. Celui-ci permet de récupérer une partie de la chaleur des gaz d'échappement et contribue ainsi à améliorer la consommation spécifique de combustible. La température des gaz à l'admission de la turbine haute pression est maintenue constante à 600° C. dans un vaste domaine de charge de la turbine, ce par l'interme-

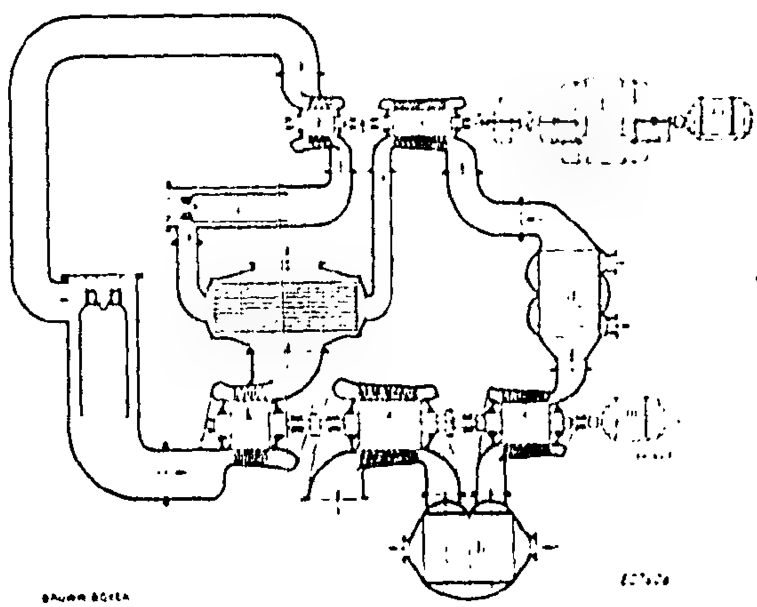

Fig. 2 — Schéma de l'installation à turbine à gaz de Lima

a — Compresseur b.p.; b — Réfrigérant d'air I; c — Compresseur m.p.; d — Réfrigérant d'air II; e — Compresseur h.p.; f — Récupérateur de chaleur; g — Chambre de combustion h.p.; h — Turbine à gaz h.p.; i — Chambre de combustion b.p.; k — Turbine à gaz b.p.; l — Alternateur triphasé; m — Moteur de lancement; n — Engrenage

[illegible] température. On arrive ainsi à faire travailler [illegible] optimum, même à charge partielle. Le système de réglage adapte automatiquement la vitesse du groupe basse pression à la charge demandée. La fig. 4 représente une vue générale de la turbine à gaz de Lima.

La consommation d'eau de réfrigération d'une installation à plusieurs étages de compression est nécessairement plus grande que celle d'une turbine à un seul étage. La turbine à gaz de Lima nécessite environ 500 m³ d'eau de réfrigération à l'heure. Ce n'est cependant guère que le cinquième de la consommation d'eau de réfrigération d'une installation à turbine à vapeur de même puissance. Le combustible employé à Lima consiste en huile Diesel Esso.

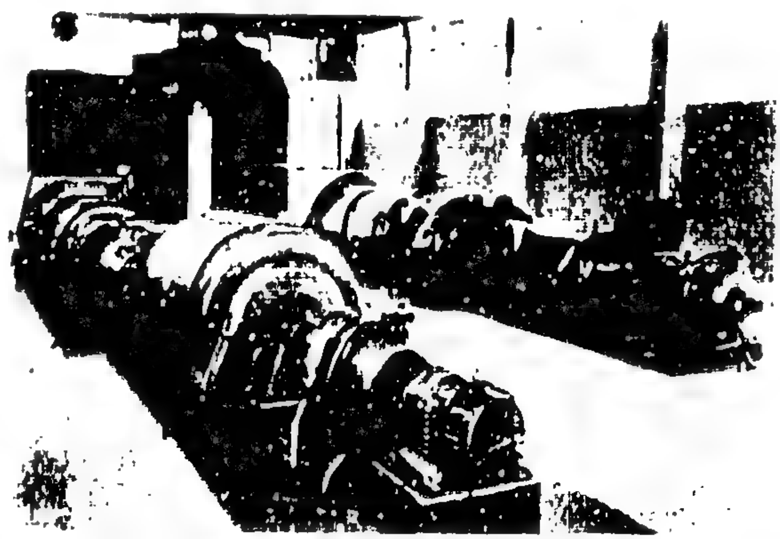

Fig. 4 — Vue de la salle des machines de la centrale à turbine à gaz de Lima à gauche: groupe haute pression avec alternateur à droite: groupe basse pression

Primitivement, l'installation ne comprenait aucun filtre à air, bien que la centrale fût située à proximité immédiate d'une fabrique de ciment. Dès le début de son exploitation, on constata que, par suite de la très forte teneur en poussières de l'air, le compresseur s'encrassait. Pour remédier à cet état de chose, on installa par la suite un filtre à air et, en même temps, on apporta quelques améliorations au compresseur. L'encrassement de ce dernier fut ainsi sensiblement diminué, de sorte qu'actuellement un nettoyage de l'aubage n'est nécessaire qu'après environ 3500 heures de marche.

Au début de l'exploitation, l'aubage du compresseur haute-pression subit une avarie. Une modification constructive au compresseur en supprima complètement la cause. Depuis lors, l'installation a été en service

pendant 7100 heures sans qu'il se produise le moindre incident. Elle a fourni en tout plus de 60 millions de KWh et a été mise en marche 522 fois. En 1950 et 1951, durant les mois d'hiver, la turbine a tourné pendant 12 à 18 heures par jour. Au cours de longues périodes, elle ne fut même arrêtée qu'en fin de semaine. Elle fut également mise à contribution pendant les mois d'été, pour fournir la puissance de pointe de la soirée. La fig. 5 représente le diagramme de service de l'installation pour le mois de mai 1951. Depuis la mise en service d'une nouvelle usine hydro-électrique en 1952, la turbine à gaz sert principalement d'installation de réserve. On prévoit cependant que, très prochainement, l'usine hydro-électrique ne sera plus à même de couvrir les besoins toujours croissants d'énergie. La turbine à gaz reprendra alors son service permanent.

Pertigalete

La centrale thermique de la C. A. Venezolana de Cementos à Pertigalete comprend trois turbines à gaz. Celles-ci sont, avec un petit moteur Diesel, la seule source d'énergie de toute la fabrique de ciment. Deux unités identiques, de 1650 KW chacune, furent mises en service à fin 1949, la troisième, de 5000 KW, fonctionne depuis janvier 1953. Les caractéristiques techniques ressortent du tableau II.

TABLEAU II

CARACTÉRISTIQUES TECHNIQUES DES TROIS TURBINES A GAZ DE LA FABRIQUE DE CIMENT DE PERTIGALETE

	Groupes I et II	*Groupe III*	
Puissance aux bornes de l'alternateur	1650	5000	KW
Vitesse de rotation de la turbine	5350	3600	t/min
Vitesse de rotation de l'alternateur	1800	3600	t/min
Quantité d'air	28	70	kg/s
Température de l'air aspiré	35	35	°C
Température à l'entrée de la turbine	600	650	°C
Rapport de compression	3,0	4,6	
Rendement combustible-bornes	21	18	%
Efficacité du récupérateur de chaleur	80	—	%

Les trois turbines de Pertigalete sont du type à une ligne d'arbres. Les deux petits groupes, I et II, sont munis d'un récupérateur de chaleur. L'air est purifié par des filtres à douilles huilées. Le combustible utilisé fut, jusqu'à fin 1952, un mélange de 60 % d'huile lourde et de 40 % d'huile Diesel. Pour le lancement de la turbine on se sert du courant produit par un petit groupe électrogène à moteur Diesel.

Au début de l'exploitation, comme une seule turbine suffisait à cou-[illegible] de ciment, les deux groupes ne fonctionnaient qu'alternativement, chacun pendant une période ininterrompue de 630 heures environ; pendant ce temps, l'autre groupe faisait office d'installation de réserve. L'exploitation de la fabrique de ciment était telle que les turbines à gaz avaient à supporter presque continuellement des variations de charge de 200 à 300 kW. Les puissances moyennes journalières se montèrent à 1500 kW environ; quelquefois des pointes de charges allant jusqu'à 1800 kW furent enregistrées. Par suite de la ra-

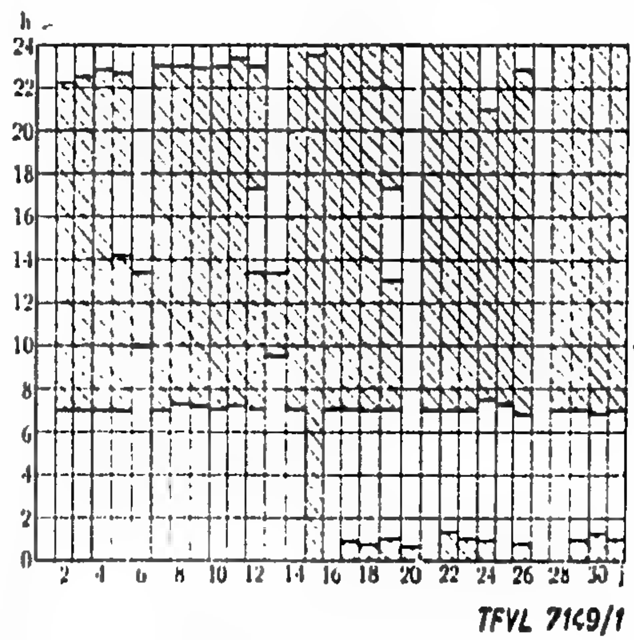

Fig. — 5 Diagramme de service de la turbine à gaz de Lima pour le mois de mai 1951
h — heure de la journée; j — jour du mois

pide augmentation de la production de ciment une turbine ne suffit bientôt plus à couvrir, seule, les besoins d'énergie. Les deux groupes durent alors fonctionner parallèlement.

A fin 1952, les deux turbines furent dotées chacune d'un brûleur à gaz et elles fonctionnent depuis lors au gaz naturel. A l'occasion de cette modification, les deux unités subirent un contrôle serré. On constata alors que toutes les parties de l'installation se trouvaient être en parfait état. On ne put déceler aucune usure notable. Nous reviendrons du reste sur le détail du résultat de ce contrôle. Les deux groupes avaient à fin août 1953 l'un 18700, l'autre 16800 heures de service. Au cours de ce laps de temps on n'eut pas à déplorer un seul accroc.

La [illegible] de la fabrique s'accroissant de plus en plus, il [illegible] un agrandissement de la centrale thermique. Sur la [illegible] expériences faites avec les deux premiers groupes, on résolut d'installer une nouvelle turbine à gaz. Ce nouveau groupe, d'une puissance nominale de 5000 kW, fut mis en service en janvier 1953. Prévu pour fonctionner principalement au gaz naturel bon marché, son rendement n'était que d'importance secondaire. C'est pourquoi on renonça à l'installation d'un récupérateur de chaleur. Tous les dispositifs nécessaires à la marche au combustible liquide sont cependant prévus, si bien qu'en cas de nécessité on peut, d'un moment à l'autre, marcher à

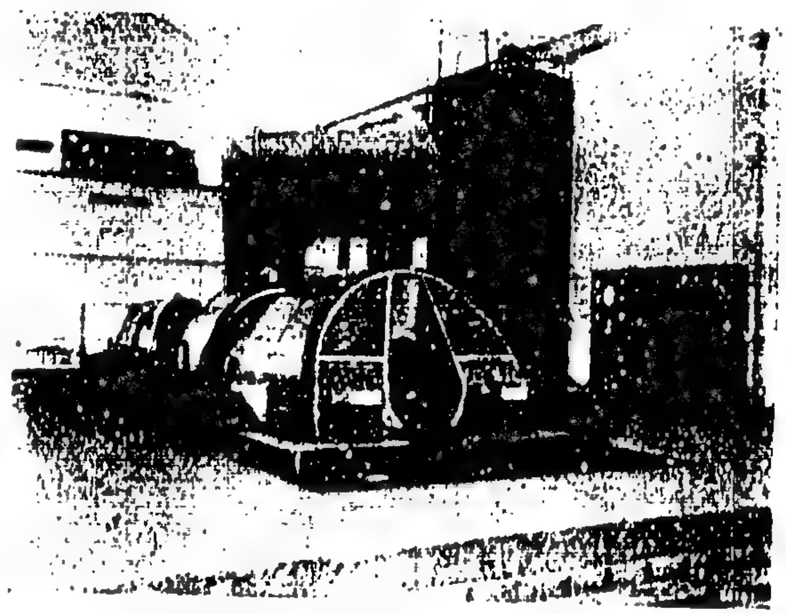

Fig. 6 — Vue générale de la turbine à gaz de 5.000 kW de Pertigalete

l'huile lourde. Cette turbine à gaz a déjà atteint jusqu'à fin août 1953 une durée de service de 1010 heures. Elle travailla jusqu'alors sans aucune panne. (Fig. 6)

Une quatrième turbine à gaz, de 5000 kW, identique à celle du groupe III décrite ci-dessus, sera encore montée dans la centrale de Pertigalete dès le début de 1954.

EXPÉRIENCES D'EXPLOITATION

Nous aimerions maintenant donner connaissance des expériences faites avec ces installations à turbines à gaz au cours des longues années de leur exploitation dans l'industrie.

Compresseur

Sur les deux premières turbines à gaz mises en service, on eut à enregistrer une avarie à l'ailetage du compresseur. Sur la base de cette expérience, la construction fut quelque peu modifiée. L'amélioration s'est révélée efficace. Cette avarie ne se reproduisit en effet ni dans ces installations, ni dans les turbines à gaz mises en service plus tard, qui, déjà, avaient bénéficié de l'enseignement recueilli. Toutes les turbines à gaz d'Amérique du Sud mentionnées ici sont pourvues d'un filtre à air. Malgré cela, il se vérifia que, par suite de la très haute teneur en poussière de l'air, l'ailetage du compresseur s'encrassait légèrement, de sorte qu'après une période de marche de 3000 à 4000 heures un nettoyage est nécessaire. Les expériences faites en Europe prouvent qu'avec un air suffiseur ne doit être nettoyé qu'une fois par an.

Chambre de combustion

Même après plusieurs années de service, les parties internes des chambres de combustion des installations marchant au combustible gazeux ne présentent aucune détérioration. On peut donc compter sur une très longue durée de la chambre de combustion. Lorsque des combustibles lourds, riches en cendres, sont utilisés, il faut s'attendre à une légère oxydation des parties se trouvant à proximité immédiate de la flamme. Les revêtements intérieurs des chambres de combustion modernes sont constitués par de petites plaques facilement remplaçables. Il est ainsi possible de remplacer les parties détériorées pendant un temps d'arrêt normal de la turbine, par exemple au cours d'un week-end. A Pertigalete, par exemple, le 20% seulement de ces revêtements intérieurs dut être remplacé au cours de 17500 heures de service. Le coût de ce remplacement se monta à environ 0,008 U.S. cents par KWh fourni.

Les injecteurs de combustible liquide s'usent lentement, spécialement si le combustible contient des impuretés. Certaines parties intérieures de l'injecteur doivent de ce fait être remplacées après une durée de service de 1000 heures environ.

Turbine

Dans les installations marchant avec du combustible gazeux ou du combustible liquide ne contenant que peu de cendres, un encrassement de la turbine n'est pas à craindre. Si l'on emploie du combustible à forte teneur en cendres, il se produit un encrassement de l'aubage de la turbine. Normalement, on peut facilement y remédier par lavage. Les turbines de Pertigalete, par exemple, sont lavées périodiquement, après 700 à 900 heures de service. Le lavage d'une turbine à gaz est une opération très simple qui se fait sans qu'il soit nécessaire de démonter

aucune pièce. Après que la turbine soit quelque peu refroidie, on l'entraîne par le moteur de lancement et, en même temps, on y injecte de l'eau au moyen du dispositif de lavage incorporé prévu à cet effet. La durée de l'opération n'est que d'une heure environ. Nos expériences ont montré que l'aubage d'une turbine peut ainsi être parfaitement nettoyé.

Au cours du contrôle de la turbine de Pertigalete, après environ 15000 heures de service, on n'a pu déceler aucune trace de corrosion ou d'usure quelconque. Les expériences faites avec d'autres installations à turbines à gaz prouvent que, même si l'on travaille avec du combustible à haute teneur en cendre, contenant du vanadium, et même avec une température des gaz de 650° C, aucune corrosion n'intervient. Il est donc maintenant déjà établi que l'aubage des turbines à gaz aura une très longue durée de service.

Récupérateur de chaleur

De légers dépôts de cendres et de suie peuvent se former sur les tubes des récupérateurs de chaleur. C'est pourquoi, dans les installations modernes, ces derniers sont pourvus de "souffleurs de suie" spéciaux, grâce auxquels les dépôts peuvent être éliminés pendant la marche de la machine. Les expériences ont montré que ces souffleurs de suie sont très efficaces et qu'ils remplissent parfaitement leur fonction.

A Pertigalete, un tube de récupérateur de chaleur fut sorti, après plus de 15000 heures de service, pour contrôle. Il était encore à l'état de neuf et ne présentait aucune trace de corrosion, de sorte que l'on peut également compter sur une longue durée des récupérateurs de chaleur.

Huile de graissage

La consommation d'huile de graissage d'une installation à turbine à gaz est très minime. Différentes analyses ont montré que l'huile de graissage d'une turbine à gaz vieillit moins rapidement que celle d'une turbine à vapeur. Un remplissage suffit donc pour une période d'environ 5 ans.

Combustible

Les trois turbines à gaz d'Amérique du Sud travaillent avec du combustible liquide ou gazeux. A Pertigalete, par exemple, on employa un mélange de 60% d'huile lourde du Venézuela et de 40% d'huile Diesel. D'autres turbines à gaz, en Europe et en Orient, travaillent uniquement avec des huiles lourdes. Les turbines prévues pour un fonctionnement au combustible gazeux sont généralement pourvues également d'un brûleur à huile lourde pouvant être mis en fonction en cas de manque de gaz. On a récemment réalisé des brûleurs permettant de passer, sans interruption de service, d'un combustible à l'autre ou même de brûler en même temps les deux sortes de combustible, gazeux et liquide.

Exploitation

Pour les régions tropicales et subtropicales, on exige avant tout des installations dont l'exploitation est très simple et qui ne nécessitent qu'un minimum d'entretien. A cet égard, la turbine à gaz simple, à une seule ligne d'arbres, surpasse toutes les autres installations thermiques de production d'énergie. Il ressort de ce qui précède que les turbines à gaz ne nécessitent que peu de travaux d'entretien, du reste faciles à exécuter en un temps très court.

Toutes les installations mentionnées plus haut sont deservies par du personnel indigène, préalablement mis au courant. Pour l'exploitation d'une installation à une ligne d'arbres, un à deux hommes suffisent; deux à trois hommes sont nécessaires pour une machine à plusieurs lignes d'arbres.

Les opérations de mise en marche et d'arrêt d'une installation à une ligne d'arbres sont très simples.

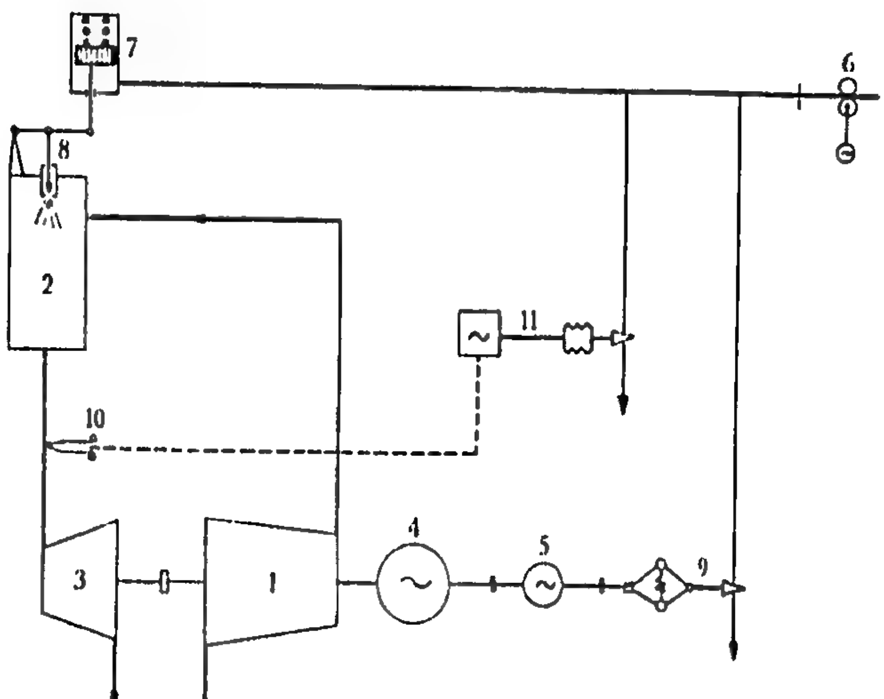

Fig. 7 — Schéma de la régulation de la turbine à gaz de Chimbote

1 — Compresseur; 2 — Chambre de combustion; 3 — Turbine à gaz; 4 — Alternateur triphasé; 5 — Moteur de lancement; 6 — Pompe à huile; 7 — Servomoteur; 8 — Injecteur du combustible; 9 — Régulateur de vitesse; 10 — Thermocouple; 11 — Régulateur de température.

Le temps de démarrage d'une turbine est compris entre 15 et 20 [illegible]é, un tel groupe peut même démarrer, de l'arrêt à la marche à pleine charge, en 10 minutes environ.

Réglage

Le réglage d'une turbine à gaz à une ligne d'arbres est particulièrement simple. La fig. 7 montre le schéma de réglage de la turbine de Chimbote. Le régulateur de vitesse de la turbine varie la pression de l'huile du système de réglage et, par suite, l'ouverture de l'injecteur de combustible. Ainsi, la quantité de combustible injecté dans la chambre de combustion est constamment adaptée à la charge de la turbine. Ce réglage réagit très rapidement, il est absolument stable.

Les turbines à gaz sont également pourvues des dispositifs de sécurité indispensables. Un régulateur de survitesse déclanche automatiquement toute l'installation quand la vitesse du groupe dépasse de 10% sa valeur normale. Le régulateur de température d'une turbine à gaz à une ligne d'arbres n'entre en action que lorsque la température des gaz à l'entrée de la turbine dépasse sa valeur maximum admissible; il abaisse alors la pression d'huile du circuit de réglage jusqu'à ce que la température des gaz soit redescendue. Une détérioration de l'installation par suite de trop hautes températures est ainsi évitée.

Résumé

Depuis 1949, plusieurs installations à turbines à gaz sont en service industriel en Amérique du Sud. Elles sont toutes du type à cycle ouvert. Une installation simple, à une seule ligne d'arbres, est montée à Chimbote (Pérou). Elle tient lieu d'installation de réserve pour une usine sidérurgique. Une turbine à gaz à deux lignes d'arbres, d'une puissance de 10000 kW, fournit son énergie au réseau électrique urbain de Lima. La centrale thermique de la fabrique de ciment de Pertigalete (Vénézuela) comprend trois turbines à gaz, constituant l'unique source d'énergie de toute l'usine. Deux de ces unités, de 1650 kW chacune, ont à leur actif, l'une 18100, l'autre 16800 heures de service; elles ont fonctionné durant cette période sans aucun accroc.

La turbine à gaz à une ligne d'arbres et à cycle ouvert est de construction particulièrement simple. Son exploitation est aisée et n'exige que peu d'entretien. Si le combustible utilisé est riche en cendres, la turbine à gaz doit subir périodiquement un lavage, opération rapide et simple grâce au dispositif de lavage incorporé. Aucune usure des aubages de turbines à gaz n'a pu être décelée jusqu'ici. Seules quelques pièces internes des chambres de combustion s'oxydent lentement doivent, après une longue durée de service, être remplacées.

Les turbines à gaz alimentées par des gaz naturels ont également [illegible] les aubages de ces turbines ne nécessitent aucun lavage. On n'a pas encore pu déceler la moindre usure de leurs chambres de combustion.

Les expériences faites avec ces installations au cours de plusieurs années d'exploitation industrielle prouvent bien que la sécurité de marche de la turbine à gaz est aujourd'hui aussi grande que celle de n'importe quel autre genre d'installation thermique. La turbine à gaz a fait ses preuves aussi bien en service continu qu'en service intermittent.

Summary

Since the year 1919, several gas turbines are in South America in industrial operation. All of these gas turbines operate on the open cycle principal. In Chimbote (Peru), a single stage group of 4000 kW is installed. This group serves as a stand-by unit for a metallurgical works. A multi-stage gas turbine of 10000 kW output, supplies energy for the city of Lima. There are 3 gas turbines installed in a cement works in Pertigalete (Venezuela). These gas turbines represent the only source of power for the whole factory. Two units each of 1650 kW have already run for 18100 and 16800 hours respectively and in this time no difficulties have been encountered.

The single stage, open cycle gas turbine plant is especially simple, and therefore requires very little servicing and repairs. For the use of fuels with a high ash content, the turbine must be periodically washed. This work is simple and can be accomplished in a short time by means of the built-in washing equipment. Up until now no wear has been observed on the gas turbine blades. Only a few parts of the combustion chamber burn out slowly and have to be replaced after many operating hours.

Gas turbines operating on natural gas have produced very good results. On such plants, the turbine blades do not need to be washed. No deterioration whatever has been observed in the gas-fired combustion chambers.

Experience gained with gas turbines after many years of industrial operation has proved that the gas turbine today is as dependable as any other thermal prime mover. Furthermore, the gas turbine is as equally suited to continuous operation as it is to service with frequent starting and stopping

Resumen

En América del Sud están en servicio industrial varias plantas con turbina a gas desde el año 1919. En Chimbote (Peru) hay una turbina a gas de una etapa de 4000 kW. Esta sirve como máquina de reserva para

la planta siderúrgica. Un grupo de 10000 kW de dos ejes suministra ener[illegible]udad de Lima. En la planta eléctrica de la fábrica de cemento de Pertigalete (Venezuela) se encuentran 3 turbinas a gas. Estas forman la unica fuente de energía para toda la fabrica. Dos unidades de 1650 kW cada una tienen ya 18100 resp. 16800 horas de servicio y han trabajado durante este tiempo sin avería.

La turbina de ciclo abierto de un eje es extremamente simple y por lo tanto exige muy poca atención y mantenimiento. Usando combustible pesado con alto contenido de ceniza, hay que limpiar la turbina periodicamente; es un trabajo que se puede efectuar fácilmente y en poco tiempo con el dispositivo de lavado instalado a tal efecto. Hasta hoy no se ha podido observar desgaste alguno en las aletas. Solamente algunas piezas interiores de la cámara de combustión tienen un desgaste paulatino y deben ser reemplazados después de un tiempo de servicio másomenos largo.

Las turbinas alimentadas con gas natural han asimismo dado muy buenos resultados. En estas plantas no se debe nunca lavar las aletas de las turbinas. Ningún desgaste pudo todavia constatarse en la cámara de combustión.

Las experiencias en servicio industrial hechas con estas turbinas durante varios años demuestran que la turbina a gas ofrece la misma seguridad de servicio como cualquier otra planta térmica y ha probado su eficiencia tanto en el servicio continuo como también en los casos donde se requiere muchos arranques y paradas.

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Assunto 3.2

REUNIÃO PARCIAL
SECTIONAL MEETING
Rio de Janeiro — 1954

SMITH (G.H.)
STEWART (D.)
Inglaterra

THE PRODUCTION AND REFINING OF SHALE OIL A SURVEY OF RETORTING AND REFINING METHODS

By G. H. SMITH
MC, PhD, ARTC, FRIC, FInstPet, Chief Chemist Scottish Oils, Ltd
and D. STEWART
BSc, PhD, AH-WC, FRIC, FInstPet, Deputy Chief Chemist Scottish Oils, Ltd
BRITISH NATIONAL COMMITTEE

The production of oil from coal in Britain dates back to the 17th century, but the first plant for the production of oil from shale was started by Selligue in France in 1838. In 1851 Young erected plant in Scotland to manufacture oil from Boghead coal, and when this became exhausted the shales of the Lothians were used successfully as raw material.

Oil shales are very widespread over the earth's surface, and shale oil industries exist, or have existed, in many parts of the world as indicated below:

Europe:	Scotland, France, Sweden, Spain, Germany and Estonia.
Asia:	U. S. S. R., Manchuria, Burmah.
Australasia:	New South Wales, Tasmania and New Zealand.
South Africa:	Ermelo district of the Transvaal.
South America:	Brazil.
U.S.A.:	Colorado.

Little or no organic matter can be extracted from oil shales by the usual solvents. Rather do they contain the altered remains of vegetable and animal life which on destructive distillation yield hydrocarbon gases and liquids. The nature of the mineral matter in oil shales varies widely, but generally it is either calcareous or argillaceous.

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M[illegible] the types of retort which have been used or proposed for the production of oil from oil shale, while methods of [illegible] extent according to the finished products desired. It is the purpose of this paper to survey briefly the principal retorting processes which have been evolved and indicate various methods which have been adopted to refine shale oil.

MINING OF OIL SHALE:

Methods of mining oil shale are largely dependent on the depth of the shale below the surface and on the thickness of the bed which it is desired to recover. Opencast methods of mining are used in Sweden, where the overburden to be removed is 19.7 to 26.2 ft. (6-8 metres) and the thickness of the shale seam is 32.5 to 52.5 ft. (10-16 metres). Opencast mining of shale is also practised in Scotland, France, Estonia and Manchuria. In the deep mining of oil shales, vertical or inclined shafts are driven to the shale and the mineral is extracted by accepted coal mining methods, modified to suit the nature of the mineral and the thickness of the seam. Deep mining of shale is practised in many countries, for example, Scotland, Estonia, France and Spain.

Owing to the great thickness of the seams (73 ft. or 22.25 m.) in the shale deposits of Colorado, U. S. A., and to the fact that these outcrop on a cliff face, underground quarrying methods are proposed and an experimental working is in being at Rifle, Colo. (1) Adits are driven horizontally into the shale and the mineral is recovered by the aid of explosives. The roof is supported by pillars of shale left in place.

PREPARATION OF OIL SHALE FOR RETORTING:

When the shale is obtained from surface or underground workings, the oil is invariably recovered from it by heating the mineral to a temperature of at least 800/900°F. (427/482°C.)

Generally the shale must be prepared in some way before it is suitable for charging to the oil recovery equipment or "retorts". For example, unwanted non-oil bearing rock may be removed, as in the case of limestone in the shale in Sweden. Thereafter the shale is crushed to a size which is dependent on the type of retort employed and fines may be screened out and rejected. Usually a maximum size of 4" (10.2 cm.) cube is used, but some retorts require pieces as small as 1 1/2" (3.8 cm.) and graded in a narrow range — notably the Kvarntorp retort used by the Swedish industry.

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(1) U. S. Bureau of Mines: Reports of Investigation: — 4652, 1950, p. 5, 4771, 1951, p. 3, 4866, 1952, p. 2

[illegible] OIL SHALE:

[illegible] a low temperature carbonisation process. A retort of good design should have the following features:

(1) The heat exchange between the shale, products of distillation and the heating medium should be good, delivering the oil product and the shale ash at temperatures not greatly above that of the atmosphere.

(2) The retort should be self-supporting as regards fuel for its operation. This is usually brought about by making use of some of the heat in the incondensible shale gases, or of the residual carbon in the de-oiled shale.

(3) The retort should have the minimum of moving parts exposed to high temperature or to abrasive wear.

(4) Construction, maintenance and operational labour costs should be low.

These requirements demand the use of continuously operated equipment, preferably built in units having a large specific throughput. The design and operational principles of such equipment vary widely and successful shale retorts may be classified very broadly as:

(1) Externally or indirectly heated.

(2) Internally or directly heated.

There are many variations and modifications of these two systems and some retorts make use of both principles simultaneously.

Retorts may thus be further classified under the two systems, as follows:

(1) *Externally heated Retorts.*

(a) Static retorts — batch or continuously operated.

(b) Retorts in which the charge is stirred or otherwise kept in motion.

(2) *Internally heated Retorts.*

(a) Those heated by hot gases produced by the combustion of gas or of residual carbon in the retort itself. Retorts of this type may be batch or continuously operated.

(b) Those in which the shale is heated by circulating gases or vapours, which are themselves heated by the combustion of fuel outside the retort

(3) Retorts in which the heat for pyrolysis is got partly through internal heating and partly by the passage of heat through walls.

Examples of retorts classified in this way are as follows

(1) (a): The original retorts used in Scotland and in France were horizontal or vertical closed cast-iron batch retorts. These were followed by vertical continuous iron and firebrick retorts such as were employed by the Scottish industry (2) up to about 1935, and the Swedish modification known as the H. G. or Rockesholm retort. (3) The most recent type, however, is the Kvarntorp retort (4) which has been adopted as the standard unit in the Swedish industry.

(1) (b): Probably the best example of the externally heated mechanically agitated type is the Davidson (5) rotary retort, which is in use in Estonia and in South Africa. The Salermo (6) retort comes under this heading, and is also used in the South African plant.

(2) (a): Retorts using this principle include the N. T. U. (7) a downward heating batch unit, and the German modification, the Sweitzer. The best known of this class, however, is probably the Pintsch (8) type of retort employed by the Estonian industry, and its modification which is used in considerable numbers at Fuschun in Manchuria. These are continuous upwardly heating retorts and should be compared with the experimental Union (9) retort of U. S. A., in which the shale moves upwards countercurrent to the descending hot gases.

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(2) Bailey, E. M. The Oil Shales of the Lothians, 1927, p. 191
(3) O. E. E. C. Documentation — Report of Tech. Assistance Mission No. 93 — Swedish Shale Oil, 1952. p. 27.
(4) do do p. 24
(5) Davidson, T. M. Oil Shale & Cannel Coal, Vol. I, 1938, p. 157.
(6) Forbes C. E. and Semerville Oil Shale & Cannel Coal, Vol. II, 1951, p. 431.
(7) U. S. Bureau of Mines Report of Invest. 4652, 1950, p. 16.
(8) Luts, K. Oil Shale & Cannel Coal, Vol. I, 1938, p. 133.
(9) Berg, Clyde. Oil Shale & Cannel Coal, Vol. II, 1951, p. 419.

(2) (b) In this class are the Otto [10] retort from Germany, the [illegible] [11] retort from France and the experimental gas flow retort of the U. S. Bureau of Mines. The tunnel kilns [12] used in Sweden and in Estonia may also be grouped under this heading.

(3) An outstanding example of this type is the Westwood [13] retort, a modification of its forerunner, the Pumpherston retort. This is the standard unit in the Scottish industry at the present time.

A typical retort in each section will now be briefly described.

(1) (a) – *The Kvarntorp Retort* (*Sweden*) (Fig. 1)

These retorts are small in size and are built in units of 5 retorts to a furnace, which may from part of a bench of continuous line of 540 retorts. The Kvarntorp retort is a vertical alloy tube 7.87" (200 mm.) diam. and 7.2 ft. (2.2 m.) long, open at the top to the charging hopper and communicating with the heating furnace at the open lower end. Vapours are drawn off near the top of each tube to a common suction main and the pressures in the retort tubes and in the furnaces are so adjusted that oil vapours pass up the retorts and flue gases round them. Steam is admitted near the base of the tubes to seal off the flue gases from the distillation products and to aid in heat distribution and the carry over of oil vapours. An important feature is that the high residual carbon content of the de-oiled Narké shales is made use of to produce high pressure superheated steam in La Mont tubes around the retorts and embedded in the burning shale. This latter provision also controls the furnace temperature to prevent fusion of the shale ash. The throughput of each Kvarntorp tube is only 0.89 ton per day, but the retort was designed specifically to handle a particular type of oil shale. The recovery of oil is approximately 85% of Fischer assay.

(1) (b) – *The Davidsen Rotary Retort* (*Estonia and South Africa*)

This retort consists of a slowly-rotating, externally heated inclined steel tube which may be as much as 75 ft. long and 4 ft. diam (22.86 m. x 1.2 m.).

Broken shale gravitates through the tube, which rotates at a speed of about 1 r.p.m., before passing through a seal into a furnace in which the free carbon in the de-oiled shale is burned off. Shale ash is removed

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(10) Smith G. H. and Caldwell J. M., B. I. O. S. Report No. 1221, 1946, p. 9
(11) Tiellard, d'Eyry J., Oil Shale & Cannel Coal, Vol. I, 1938, p. 184
(12) Keltzer K., do. do. p. 143
(13) Smith G. H. and Balloch A., do. Vol. II, 1951, p. 399

[illegible] ... the retort are drawn off through fixed [illegible] tubes, the whole retort being under slight suction.

(2) (a) — *The [illegible] Retort (Estonia)*

This is a straight forward vertical cylindrical retort in which the heat for pyrolysis is obtained by combustion of the residual carbon in the de-oiled shale near the retort base. Temperatures in the distillation zone midway up the retort are controlled by the recirculation of permanent shale gas to ports in the retort shell. The distillation zone temperature is thus controlled at 950-1100 F. (510-593 C.), while the maximum temperature in the combustion zone may reach 1800 F. (98[illegible] C.).

(2) (b) *The Grande Paroisse Retort (France)*

This retort consists essentially of a vertical rectangular sectioned shaft with louvres on the two long sides. Above the main distillation

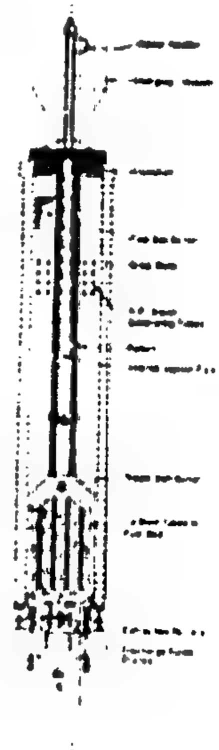

Fig. [illegible] — Cross section of Kvarntorp Retort (reprinted from O.E.E.C. Report of Tech Assistance Mission n° [illegible], 1952, — Swedish Shale Oil)

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[illegible]

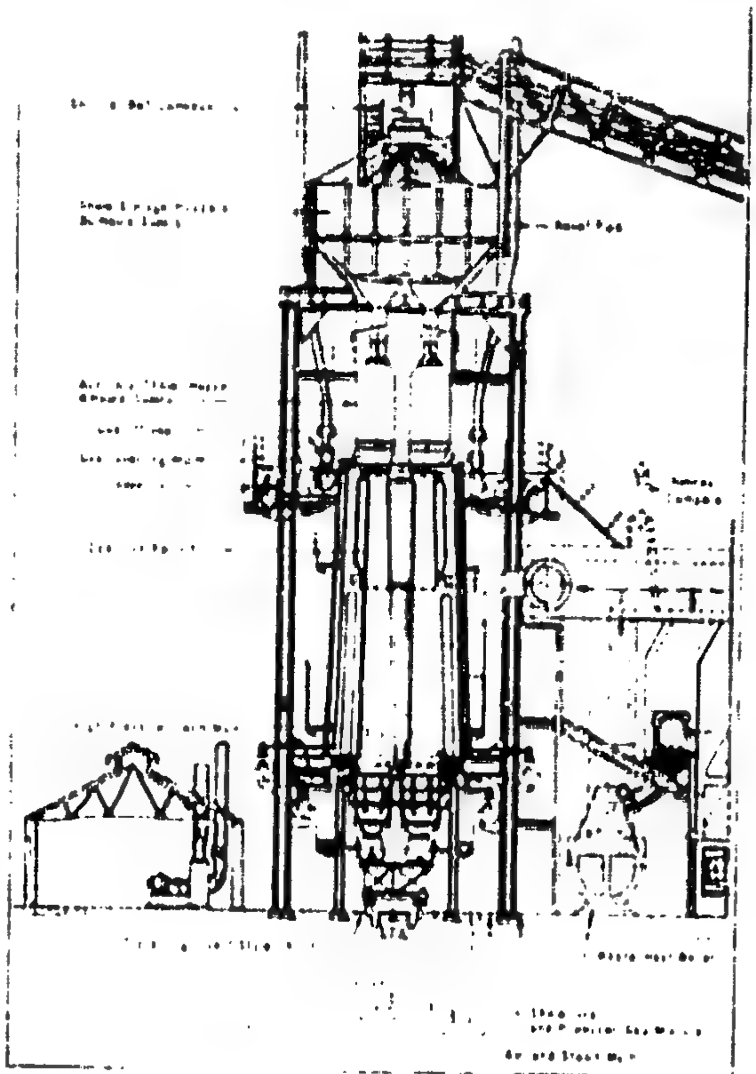

Fig. 2 — Sectional Drawing of [illegible]

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The main distillation section is heated by the transverse flue [illegible] [illegible] 930°F (500°C) by passage through externally heated tubes

(3) *The Westwood Retort (Scotland and Spain)* Fig. 2

This is a much modified version of the conventional Scottish type iron and firebrick vertical continuous retort. As compared with the purely externally heated retort it gives improved fuel economy and increased throughput.

The Westwood retort is rectangular in cross section and is 34 ft long (10.36 m). It increases in cross section from 2'9" × 1'2" (0.85 m × 0.37 m) at the top to 4'6" × 1'10" (1.42 m × 0.56 m) at the base. The upper 14 ft (4.27 m) of the retort is a one piece iron casting of oval cross section. This is superimposed on the rectangular sectioned firebrick portion 20 ft (6.10 m) long. The retort is fitted with a mechanically driven spider-type extraction gear for spent shale and the hot shale ash which discharges into a closed hopper is continuously sprayed with hot water to cool the ash and to generate part of the steam used in the pyrolysis.

Exhaust steam and a carefully controlled quantity of air are admitted to the base of the retort. The steam reacts with the carbon in the de-oiled shale to give water gas and with nitrogenous compounds to give ammonia while at the same time acting as a carrier for the oil vapours. The injected air promotes combustion of part of the residual carbon in the de-oiled shale and thereby generates a large part of the required heat inside the retort itself. The maximum temperature inside the retort in the lower part is about 1400°F (760°C). This retort has so far been standard in the Scottish industry and has recently been adopted in a new Spanish plant at Puertollano.

Gas Combustion Retort (U. S. A.) (14)

Mention must be made of the considerable amount of work which has been done by the U. S. Bureau of Mines on the design of shale retorts culminating in their Gas Combustion retort (Fig. 3). So far only demonstration units have been erected. In this retort, which consists of a vertical static shaft of round or rectangular cross section, the shale passes downwards continuously. Permanent shale gas is circulated through the retort countercurrent to the descending shale and air is injected in carefully controlled quantity just below the mid point in the column. Combustion of part of the ascending gas and some of the free

(14) U. S. Bureau of Mines Report of Investigations 4866, 1952, p. 16.
do do 4943 1953, p. 15.

[illegible]

UNDERGROUND DISTILLATION OF SHALE

While oil shale is generally won by conventional mining methods and the oil is recovered by retorting the shale in a plant, at least two attempts have been made to recover the oil from the shale in situ. The most important of these methods is that devised by Dr. Ljungstrom and employed on a considerable scale in the Narke province of Sweden (15).

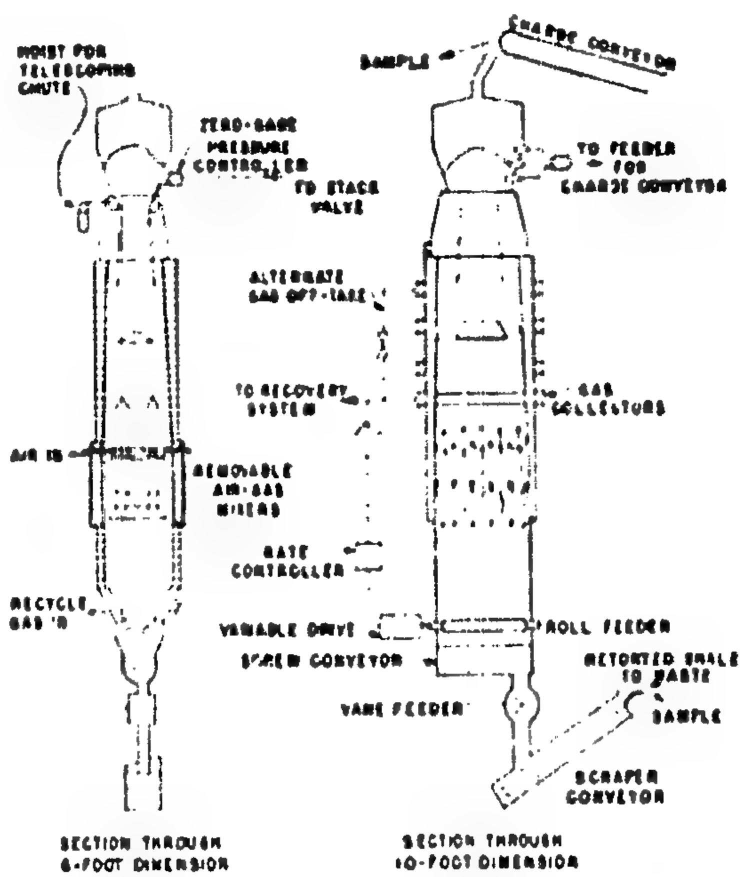

Fig. 3 — Gas Combustion Retort — U. S. Bureau of Mines (reprinted from U. S. Bureau of Mines Report of Investigations [illegible], Jan. [illegible])

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[illegible] electric heating elements [illegible] at the [illegible] hexagonal to heat [illegible] there is a larger central hole up which the distillation products are drawn to condensers on the surface. At the present time from 14,000 to 24,000 kW of electrical energy is expended in this way in the Norrtorp field. An oil recovery of approximately 65% is obtained.

The second underground oil recovery method of note is that which was practised at Schörzingen in Wurttemburg after World War II (15). Using ordinary mining methods a number of long rectangular chambers were formed underground. The sides and roof were then blasted to fill the chambers and the spaces between them with broken shale. Brick stoppings were built at the ends of each chamber, the shale was ignited at one end and air admitted through valves. From the other end products of distillation were drawn off through mains to condensers and exhausting plant on the surface. The yield of products obtained by this method was only about one third of that from Fischer assay.

REFINING OF SHALE OIL

Shale oil being the product of decomposition of the organic matter in oil shale by the application of heat, its characteristics depend on

(1) the fundamental nature of the organic material in the shale.
(2) the conditions of application of heat to the shale.

Shale oils like petroleum can be classified as paraffin and mixed or asphalt base oils. Scottish and Australian shale oils are examples of the paraffin base type while Estonian and Tasmanian shale oils are of asphaltic type.

Broadly, shale oils differ from petroleum in that they contain compounds of oxygen and nitrogen and unsaturated hydrocarbons. A picture of the composition of shale oil in relation to coal oil and petroleum is given by Pott (17) and is reproduced in Fig. 4. This shows that the C/H ratio in shale oil (11-14H 100C) corresponds more closely to that of petroleum oils (12-14H 100C) than to that of coal oils .... (6-12H 100C).

The effect of the method of retorting, i.e. the conditions under which heat is applied to the shale, is discussed by Lankford and Morris (18) who give the properties of shale oils produced from Colorado shale by different types of retort. They show that the Pumpherston

(15) Schmidt[illegible], G. Oil Shale & Cannel Coal, Vol. II, 1951, p. 269.
(16) Caldwell, J. M. and Smith G. H., B. I. O. S. Report No. 1221, 194[illegible], p. 5.
(17) Pott, [illegible] Oil Shale & Cannel Coal, Vol. I, 1938, p. 396.
(18) Lankford, J. D. and Morris, B. Oil Shale & Cannel Coal, Vol. II, 1951, p. [illegible]

[illegible]

High temperature retorting of Colorado shale has been studied at the Experimental U. S. Bureau of Mines Station at Laramie (19). Retorting at 1200° F. (650° C.) to 1500° F. (816° C.) yielded only [illegible] of the oil as determined by the Fischer assay, together with a much increased quantity of gas. The oil was of higher specific gravity and contained a larger percentage of unsaturated hydrocarbons in the naphtha range. At 1500° F. (816° C.) the naphtha consisted predominantly of benzene and toluene, and the gas contained appreciable quantities of olefins, particularly ethylene.

The refining of shale oil presents problems not usually met in petroleum refining in that the oxygen and nitrogen compounds must be substantially removed together with the unstable diolefins. Provided means are taken to eliminate oxygen and nitrogen and to eliminate or saturate the diolefins, shale oil is amenable to the same types of process as are employed in petroleum refining. Oxygen compounds may be removed by caustic soda, and nitrogen compounds and diolefins by sulphuric acid at the appropriate stage of refining but with a considerable loss in yield of products. Hydrogenation of shale oil on the other hand

Ultimate Analysis

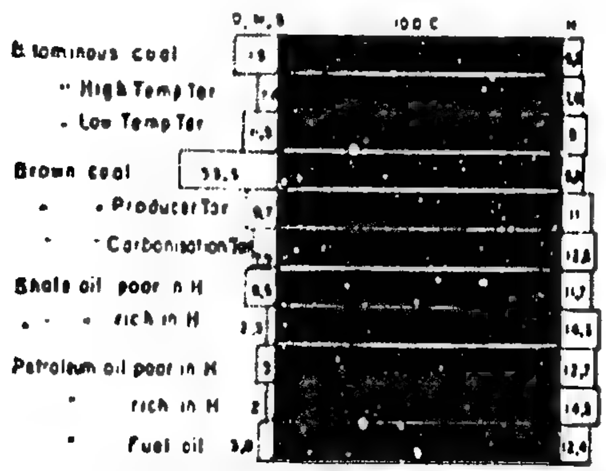


Fig. 4 Ultimate Analysis of Coal Tar, Shale Oil and Petroleum (reprinted from Oil Shale & Cannel Coal, Vol. 1, 1938, p. [illegible])

(19) Brantley F. E., Cox R. J., Sohns H. W., Barnet W. I. and Murphy W. I. R. Industrial & Engineering Chemistry, 1952, Vol. 44, p. 2642.

... 100% by vol. and over, but here the capital cost of the equipment and cost of hydrogen production are major considerations.

Refining of shale oil can be carried out in different ways depending on what products it is most economical to produce at the time.

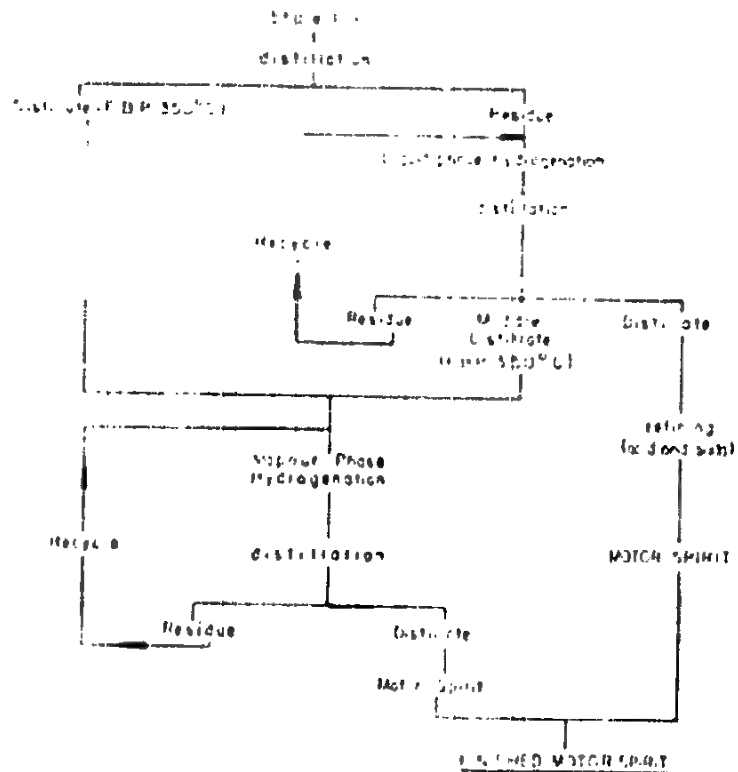
Scottish shale oil at different stages has been refined to produce

(1) Full range of products — motor spirit, solvent naphthas, kerosine, gas oil, wax, light lubricating oil and coke. (20)
(2) Maximum motor spirit
(3) Maximum motor Spirit, wax and diesel oil

COMMERCIAL REFINING OF SHALE OIL

Below are briefly outlined typical methods of refining shale oil which have been practised on a commercial scale in different fields.

(a) The preferred method of refining Scottish shale oil to-day is similar to (3) above, and this is shown diagrammatically as follows. (21)



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(20) Bailey E. M. The Oil Shales of the Lothians, 1927, p. 198.
(21) Smith G. H., Peutherer W. B. Oil Shale & Cannel Coal, Vol. I, 1938, p. 314.

This method of refining yields approximately 18% motor spirit, [illegible] diesel oil, together with works fuel and coke. Characteristics of the motor spirit and diesel oil are given below:

	Motor Spirit	*Diesel Oil*
Sp. Gr.	0.730	0.841
A. S. T. M distillation.		
I. B. P.	51°C.	177°C.
50% dist. to	111 "	279 "
F. B. P.	170 "	377 "
Sulphur	—	0.28%
Diesel index	—	53
Gum mgm./100 ml.	1	—
Octane No., motor.	58	—

As a by-product, a synthetic detergent of the secondary alkyl sulphate type is produced by sulphation of the olefins in the 200-300°C. cut. (22)

(b) Refining of Australian shale oil is described by staff of National Oil Proprietary Ltd. (23) The aim there was to produce gasoline to the exclusion of all other products, and to this end there was installed a two-coil, selective Dubbs thermal cracking unit, including coking chambers, together with a catalytic polymerisation plant. The approximate volume balance for cracking plant (yields as percent by volume on charge) is quoted as under:

Type of Operation	*Residue*	*Residue and Reformer*	*Coke*	*Coke and Reformer*
Residue	31.0	28.0	—	—
Coke	—	—	—	—
Stabilised P. D	48.0	48.2	48.5	49.0
Polymerised Gasoline	4.1	4.6	4.8	4.7
Total Gasoline	52.1	52.8	53.3	53.7
Surplus C_3C_4 gas.	12.4	12.6	17.8	16.3

The stabilised pressure distillate is refined by sulphuric acid and caustic soda treatment, re-run in an atmospheric and vacuum unit, and the distillate sweetened by plumbite and inhibited.

(22) Stewart D. and McNeill E. Oil Shale & Cannel Coal, Vol. II, 1951, p. 758.

(23) Staff of National Oil Proprietary Ltd. Oil Shale & Cannel Coal, Vol. II, 1951, p. 202.

Analysis of a typical motor spirit is given as:

Sp.Gr.	0.735
A.S.T.M.Distillation.	
I.B.P.	97°F. (36° C.)
% dist. at 100°C.	40.0
F.B.P.	376°F. (191°C.)
Gum	Stable
Octane No., C.F.R. M.M.	
+ 1.69 ml. TEL/I.G.	70.9

(c) Another example of refining shale oil to motor spirit is that of refining the crude oil from South African Torbanite at Boksburg. (24) The principle employed is similar to that at Glen Davis, Australia, but in this case bitumen is taken as an additional product. The equipment consists of a Winkler-Koch two coil cracking furnace feeding into a fractionating column, taking pressure distillate overhead and the bottoms running to a vacuum column which gives bitumen as a residue and recycle oil for the cracker. Yields from this type of operation are shown:

	% vol.
Crude pressure distillate:	50
Naphtha and kerosine for cut-back bitumen:	2
Bitumen:	39
Fuel oil:	2
Gas and loss:	7

Here again the preferred method of refining the crude spirit is by soda, acid and soda, re-running and plumbite. The yield of finished spirit is 92% vol. of the crude spirit. The Lachman zinc chloride treatment for pressure distillate has been tried, but the acid and soda method is preferred both as regards costs and yields of finished spirit.

Characteristics of the finished spirit are given as:

Sp.Gr.	0.743
A.S.T.M.Distillation:	
I.B.P.	45 C.
50% dist. at	136 "
F.B.P.	215 C.
Gum	Stable
Octane No. C.F.R. M.M.	57

The bitumen produced is of penetration 100, ductility at 77°F. (25°C.) + 100, solubility in CS_2 99.1%, setting point (ring and ball) 117°F. (47.2°C.)

(24) Robertson G. G. Oil Shale & Cannel Coal, Vol. II, 1951, p. 571.

(d) The refining of shale oil in Sweden [25] illustrates another [illegible] motor spirit and fuel oil, with a small quantity of power kerosine.

Two types of crude oil are produced:

(1) Oil from Kvarntorp, Rockesholm and tunnel kiln retorts.
(2) Oil from Ljungstrom process.

These crudes are different, the former having a specific gravity of 0.98 and giving 30% distilling to 230°C., and the latter having a specific gravity of 0.92 with 55% distilling to 230°C.

These oils are processed separately, being topped to 200°C. to give crude motor spirit and fuel oil. The crude motor spirit, including scrubber naphtha from the incondensible gas, is treated with caustic soda and sulphuric acid in three stages at 5°C., washed with water, neutralised with caustic soda and re-run. Owing to the high sulphur content of the crude spirit, the sulphuric acid treatment is heavy — 10/12½% — and the loss is high. Re-running is carried out in a three column unit, one atmospheric and two vacuum, light spirit being taken off the first, heavy spirit off the second and power kerosine off the third. The heavy gasoline and power kerosine are finished by plumbite, but the light gasoline, which contains CS_2, is treated with 15% solution of caustic soda in methanol, which also removes the mercaptans.

The light and heavy gasolines are mixed together in the proportion of 2:3, and give a motor spirit of the following characteristics:

Sp.Gr.	0.73
A.S.T.M. Distillation	
I.B.P.	47°C.
50% distilling to	121 "
F.B.P.	207 "
Gum	Stable
Octane No., C.F.R. M.M.	70/72

The above four methods of refining shale oil are typical of present day practice, and are dictated by the properties of the crude oil and conditions prevailing in these countries.

EXPERIMENTAL AND PILOT PLANT REFINING OF CRUDE SHALE OIL.

On the experimental and pilot plant scale extensive investigations into the refining of Colorado shale oil are being carried out by the U.S. Bureau of Mines at Rifle, Colorado, and at Laramie, Wyo.

(25) Lundquist L. Oil Shale & Cannel Coal, Vol. II, 1951, p. 621.

At Rifle, the Bureau constructed an experimental refinery for shale oil which was commissioned in 1949. This is fully described by Lankford and Morris. (18) The capacity of the plant is 300 B.P.D. and the plant consists fundamentally of a single coil Dubbs cracker, together with continuous acid and soda treating and continuous plumbite units. Recorded in this article are the yields and products from various types of operation, i.e. atmospheric distillation, vis-breaking, recycle cracking and delayed coking, together with analytical data on refined spirit and diesel oils.

The Bureau of Mines Report of Investigations 4866 (26) presented two plans for the production and refining of oil from Colorado shale. In both, the methods of mining and retorting are identical. In Case I the refining scheme suggested is viscosity reduction, followed by thermal cracking, with catalytic polymerisation of the C_3 and C_4 cuts, catalytic reforming of the heavy naphtha products, together with acid and soda treatment and re-running of light cracked and reformed spirits. In Case II, coking, catalytic reforming of the gasoline, hydrogenation of the diesel oil, catalytic cracking of the hydrogenated diesel oil with catalytic polymerisation of the C_3C_4 cut are employed.

The estimated oil products from these schemes, based on 250,000 B.P.D. input of crude oil, are given as:

CASE I:

Gasoline:	bbl. calendar day:	103,680
No. 6 Fuel oil.	do.	73,790
Commercial propane:	do.	13,820
Commercial butane:	do.	2,160

CASE II.

Premium gasoline:	bbl. calendar day:	63,450
Regular gasoline:	do.	63,450
Diesel fuel:	do.	62,360
Fuel oil:	do.	3,050
Commercial propane	do.	2,140
Commercial butane:	do.	6,780

Refining of Shale Oil by Hydrogenation:

It has long been realised that in order to eliminate the high losses in removing nitrogen, oxygen and highly unsaturated compounds, hydrogenation would provide the solution. To date, however while pilot plant

(18) Lankford J. D. and Morris B. Oil Shale & Cannel Coal, Vol. II, 1951, p. 502.

(26) U. S. Bureau of Mines Report of Investigations 4866, 1952, p. 44.

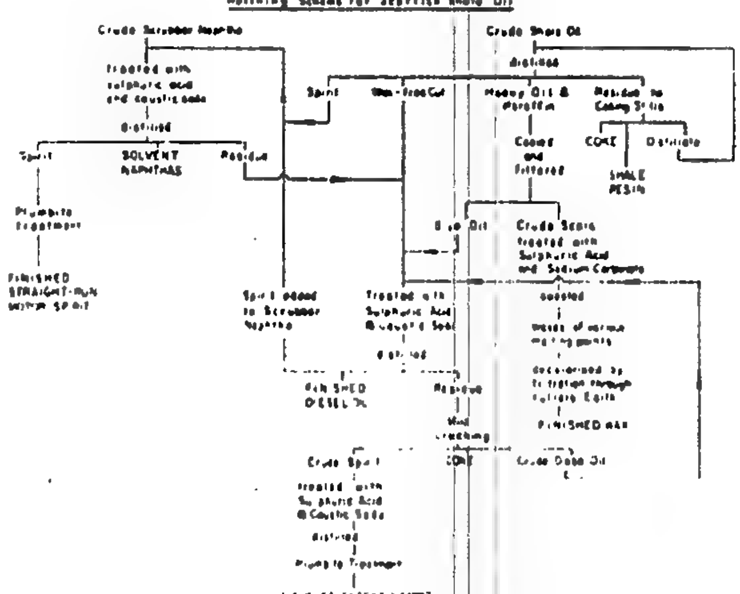
work has shown that yields of 100% vol. and over can be realised, the [illegible] It is of interest, however, to review typical methods which have been proposed for such a process:

(a) In 1935 investigations were made into the hydrogenation of Scottish shale oil and the procedure adopted was designed to produce the maximum yield of motor spirit. ([27])

This scheme, shown below, yielded 85.7% wt. or 106% vol. of motor spirit of the following characteristics:

Sp.Gr. at 60°F.	0.720
Distillation.	
I.B.P.	38°C.
50% dist. at	122 "
F.B.P.	194 "
Gum:	Stable
Octane No., M. M.	54

Refining Scheme for Scottish Shale Oil



Pier ([17]) discusses the hydrogenation of both asphaltic and paraffin base shale oils, and states that by using strongly hydrogenating catalyst a

(27) Smith G. H. and Peutherer W. B. Oil Shale & Cannel Coal, 1938, p. 337.
(17) Pier M. Oil Shale & Cannel Coal, Vol. I, 1938, p. 396.

motor spirit of O.N. [illegible] is produced from Scottish shale oil, but with certain mildly hydrogenating catalysts the octane number can be increased [illegible] with no loss in yield.

(b) Thorne, Murphy, Stansfield, Ball and Horne ([28]) hydrogenated Colorado shale oil at 800°F. (427°C.) and 1000 p.s.i., using three different catalysts — molybdena/alumina, cobalt molybdate and nickel-alumina, and showed that with cobalt molybdate catalyst a yield of 97.4% vol. can be realised. Characteristics of the hydrogenation product are given below:

Sp. Gr.	0.8456	
A.S.T.M. Distillation		
I.B.P.	150°F.	(65.6°C.)
50% dist. at	580°F.	(304°C.)
F.B.P.	761°F.	(404°C.)
Sulphur	0.06%	

(c) Hoog, Koome and Weeda ([29]) in their work on the hydrogenation of Colorado shale oil from the N.T.U. retort, showed that cracking hydrofining over cobalt-molybdenum carrier catalyst at 475°C. and 150 atm. pressure, gave 106% vol. yield of low viscosity product. This reaction product on distillation gave:

Gasoline:	26% wt.	(70-200°C. A.S.T.M.	
		(Oct. No. 40	
		(Sulphur Nil	
Diesel Oil:	51% wt.	(230-340°C. A.S.T.M.	
		(Diesel Index:	52
		(Sulphur:	0.01%
Heavy Gas Oil:	23% wt.	(Pour Point:	43°C.
		(Sulphur:	0.17%
		(Conradson	
		(Carbon)	0.5%

(d) Berg ([30]) worked out refining processes for refining the shale oil produced from Colorado shale by the Union retort. One such scheme consisted of coking the crude shale oil by the Lummus continuous contact process, followed by cobalt molybdate hydrogenation of the heavy coker distillate, together with cobalt molybdate reforming of the light coker

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(28) Thorne H. M. Murphy W. R., Stansfield K. E., Ball J. S. & Horne J. W. Oil Shale & Cannel Coal, Vol. II, 1951, p. 330.
(29) Hoog H., Koome J. & Weeda K. A. Oil Shale & Cannel Coal, Vol. II, 1951, p. 567.
(30) Berg C. Petroleum Engineer (Refining & Gas Processing), Jan., 1952, p. A. 41.

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distillate and catalytic cracking of the hydrogenated heavy coker distillate. [illegible] of the oil products derived from 100,000 bbls./day of crude oil were estimated to be:

Gasoline:	bbls.	50,700
Diesel Oil:	"	26,050
L. P. G.	"	3,570
Fuel Oil:	"	1,200
Coke:	tons.	2,360

Product Data:		*Gasoline*	*Diesel Oil*
Sp. Gr.		0.746	0.849
Sulphur.	Wt.%	0.03	0.08
Nitrogen	"	0.002	0.01
Pour Point	°F.	—	0 (-18°C.)
Knock Rating F-1 + 3 cc. TEL/U.S.G.		90.5	—
Cetane Number		—	47
Engler, 90% Point.	°F.	345 (174°C.)	610 (321°C.)
Viscosity, SSU at 100°F. (37.8°C.) secs		—	36

Summary

Since oil was first produced from oil shale in 1838, many and varied are the types of equipment which have been used for this purpose.

The essential principles of a successful retort for distilling shale are briefly indicated and the various types of retort that have been commonly employed are divided into three classes:

(1) Externally heated retorts.
(2) Internally heated retorts.
(3) Retorts employing both principles simultaneously.

A further division of these classes is included, and a brief description of one commercial retort in each class is given, viz. Kvarntorp retort, Davidson retort, Pintsch retort, the Scottish Westwood retort and the U. S. Bureau of Mines Gas Combustion retort.

Distillation of shale in situ has been practised in Sweden and in Germany.

Various methods of refining shale oil which have been in commercial use are briefly outlined. These include:

(1) The manufacture of a full range of products from motor spirit to coke.
(2) Refining to maximum motor spirit.
(3) Refining to maximum diesel oil and wax.

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The U. S. Bureau of Mines have covered in their publications an exhaustive investigation into the refining of oil from Colorado shale and have given estimates of yields of products, employing the most modern refining processes.

Technically, hydrogenation appears to be the best method of refining shale oil in that yields of 100% by vol. and over of products can be realised, but so far the cost has been prohibitive. Much work has been done in the laboratory and pilot plant scale on hydrogenation of shale oil and reference is made to typical examples.

RESUMO

Desde que o petróleo foi pela primeira vez, em 1838, obtido de xistos petrolíferos, muitos e variados têm sido os tipos de equipamento usados para êsse fim.

As características essenciais para uma boa retorta para distilar xistos são indicadas sumàriamente e os vários tipos de retortas que têm sido geralmente utilizados são divididos em três classes:

1) Retortas de aquecimento externo.

2) Retortas de aquecimento interno.

3) Retortas que empregam os dois princípios simultâneamente.

Estas classes são, por seu turno, subdivididas, seguindo-se uma breve descrição de uma retorta comercial de cada uma das sub-classes, isto é, retorta Kvarntorp, retorta Davidson, retorta Pintsch, retorta escocesa Westwood e retorta de combustão de gás do Ministério de Minas dos EE. UU. (U. S. Bureau of Mines).

Distilação de xistos "in situ" tem sido feita na Suécia e na Alemanha.

Mencionam-se vários métodos que têm sido usados comercialmente na refinação de xistos petrolíferos. Êstes incluem:

1) A manufatura de tôda a escala de produtos da gasolina ao coque.

2) Refinação de uma quantia máxima de gasolina.

3) Refinação de uma quantia máxima de óleo "diesel" e parafina sólida.

Publicações do Ministério de Minas dos EE. UU. contêm uma investigação maçuda da refinação de óleo de xisto do Colorado e dão estimativas dos produtos obtidos com o emprêgo dos processos mais modernos de refinação.

[illegible] ser técnicamente o melhor processo de refinar o óleo de xisto em virtude de ser possivel obter resultados de [illegible] produtos, mas o custo, até hoje, tem sido proibitivo.

A hidrogenação de óleo de xisto tem sido objeto de muito trabalho em laboratório e instalações de caráter experimental, pelo que se mencionam alguns exemplos tipicos.

Résumé

Depuis que l'on a produit de l'huile a partir de schistes bitumineux pour la première fois en 1838, nombreux et variés sont les équipements qui ont servi à cette fin.

Les principes éssentiels au bon fonctionnement d'une cornue à distiller des schistes sont indiqués et les différents types de cornue qui ont été courament employés peuvent se classer en trois groupes:

(1) Cornues chauffées extérieurement.
(2) Cornues chauffées intérieurement.
(3) Cornues réunissant ces deux principes.

Une subdivision de ces groupes est donnée et un modèle courant de chaque classe de cornue indiquée est succinctement décrit: les cornues Kvarntorp, Davidson, Pintsch, Westwood écossaise et la cornue à combustion de gas du Bureau des Mines des Etats-Unis.

La distillation des schistes sur place a été pratiquée en Suède et en Allemagne.

Plusieurs methodes de raffinage d'huile de schiste ont été pratiquées et elles sont décrites brièvement. Elles comprennent:

(1) La fabrication de toute une gamme de produits allant de l'essence jusqu'au coke.
(2) Raffinage pour un maximum d'essence.
(3) Raffinage pour un maximum de fuel oil et de cire.

Le Bureau des Mines des Etats-Unis a publié des informations très détaillées sur le raffinage d'huile provenant de schistes du Colorado et a donné des prévisions de production de produits en utilisant les procédés de raffinage les plus modernes.

Au point de vue technique, l'hydrogénation parait être la meilleure méthode pour le raffinage des huiles de schiste en ce que des rendements de 100% et plus par volume peuvent être réalisés mais jusqu'ici le prix de revient a été excessif. Beaucoup de travail a été fait en laboratoire et sur des installations pilotes en matiere d'hydrogénation d'huile de schiste et des exemples sont indiqués.

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[redacted] ILLEGIB

CONFERÊNCIA MUNDIAL DA ENERGIA
WORLD POWER CONFERENCE

Título 3
Assunto 3.3

REUNIÃO PARCIAL
SECTIONAL MEETING
Rio de Janeiro - 1954

WEST (J. F.)
Inglaterra

CARBONIZATION AND GASIFICATION IN TROPICAL AND SUB-TROPICAL REGIONS

By JOHN F. WEST

M. A. Cantab., M. Inst. Gas E., M. I. Mech. E.
Joint Managing Director, West's Gas Improvement Co. Ltd
— sponsored by The Society of British Gas Industries

BRITISH NATIONAL COMMITTEE

The modern trend of development in the design of carbonizing plant has been directed to the attainment of high thermal efficiency and to economy in labour cost. High thermal efficiency has been secured in part by the prevention of radiation losses, not only by means of improved surface insulation but by specialized arrangements of flues within the retort settings. Economy of labour has been obtained by complete mechanization reducing to the minimum the amount of manual labour required. But labour amenity is hardly less important. The totally enclosed systems of carbonization, in which the movement of coal to and through the system is gravitational and in which, among other means of recuperation, (particularly for instance in the continuous vertical system) the coke is cooled within the system, while designed to secure the maximum thermal efficiency, also secure a reduction to the minimum of the arduous manual labour involved in the charging and discharging of retorts and the complete elimination of the manual handling of hot coke.

The same can be said of the recent developments in the evolution of the modern carburetted water gas plant where practically the whole series of operations are mechanically performed and automatically controlled.

It follows therefore that the modern continuous vertical retort, representing carbonization, and the modern water-gas plant representing gasification, though designed in the first place to secure the maximum of thermal efficiency, are without further essential adaptation eminently

suited to use in climates where arduous manual labour is to be avoided [illegible] operating amenities are of the greatest importance.

Indeed the trend in the design of gas-making plant of all types is in the same general direction. While the intermittent vertical and even the horizontal retort and the coke oven cannot claim the same immunity from arduous labour conditions, these are greatly reduced by the mechanization as far as possible of all operations. There are no doubt instances where intermittent systems have their advantages. They may even be a necessity where coal-blending is imperative, but there seems no doubt that the present supremacy of the totally enclosed, fully mechanized systems, in tropical and sub-tropical regions is not only due to their ability to deal with all or nearly all classes of coal but to their greater labour economy and amenity.

COALS AVAILABLE

Apart then from such obvious features as modifications in the design of the buildings in which plant is enclosed there are no essential differences in the design of carbonizing plant installed in tropical and sub-tropical regions and in higher latitudes

The difference is rather in the coals available. In some cases these are entirely indigenous; in others indigenous coals are either insufficient in quantity or so unsuitable in quality as to need supplementing by, or mixing with, imported coals. Coals available for importation have changed drastically in the last decade. It may be said with a considerable degree of certainty that the U.S.A., whose coal reserves are computed to constitute 40 per cent of the world's known reserves, is the only highly industrialized country which today is in a position to export coal in large quantities.

To illustrate the results obtained in the regions under discussion we have collected returns from Santiago de Chile, Rio de Janeiro, São Paulo, Santos, Johannesburg, Hong-Kong and Tokio.

SANTIAGO de Chile, situated at latitude 38° S, stands 1700 feet above sea level with an average barometric pressure of 715 mm Hg.

The following is an abstract of gasmaking results for the year 1952 which correspond very closely with those of the first part of 1953.

1) Total quantity of coal used .... 162,615 tonnes 160,081 tons (2240 lb)

2) Average proximate analyses of coals used during the year (both indigenous varieties).

	Schwager	Lota	
Moisture	3.20%	3.37%	by weight
Volatile combustible matter	39.00%	37.55%	
Fixed carbon	49.83%	49.07%	
Ash	7.97%	10.01%	
Proportions used	64 %	36 %	
Coke	57.80%	59.08%	
Swelling Index	1 - 1½%	1½ - 2½%	
Sulphur	1.51%	1.26%	

3) Total gas made .... at 15° C & 715 mm dry at 60° F & 30" Hg. sat.

Coal gas	82,765,837 m³	2,796,875,000 cu.ft.
C. W. G.	23,733,793 m³	802,027,000 cu.ft.
Total	106,499,630 m³	3,598,902,000 cu ft.

4) Average yield of gas from all plant:

508 m³/tonne @ 15° C & 715 mm dry .... 17,440 cft/ton @ 60° F, & 30" sat.

Average calorific value of gas made:

3,950 kg-cal/m³ ...... 461 B.Th.U./cft @ 60° F & 30" saturated.

5)

Coke made	76,565	tonnes	75,358	tons
Coke sold	30,247	tonnes	29,771	tons
Coke to producers	39,654	tonnes	39,026	tons
Coke otherwise used on the works	6,666	tonnes	6,561	tons

Coke proximate analysis:

Moisture	19.7 %
Volatile combustibles	1.3 %
Ash	13.7 %
Fixed carbon	65.3 %
Sulphur content	1.16%

6) Tar: Total production .... 12,144 tonnes .... 11,953 tons.

7) Gasmaking Plant.

The first installation of Glover-West continuous vertical retorts was started up in 1927. It consisted of 18 retorts 33" (84 cm.) x 25 feet (7.6 m.) long in 6 settings with a nominal daily capacity of 81,600 m³ (2,880,000

cu.ft.). At that time annual sales of gas were approximately 21 mill m³ [illegible] 4 settings of similar retorts were added in 1930 and a third equal and similar extension in 1935, making a line of 11 settings of 35" (81 cm.) retorts with a nominal daily capacity of 190,000 m³ (6,700,000 cu.ft.). Annual sales were then 47.78 mill.m³ (1,687 mill.cu.ft.) and rising rapidly. An entirely new bench of Glover-West continuous verticals was placed on order in 1938. It was to consist of the 85" (2.16 m.) retorts with double helical coke extractors. The first four settings with a nominal daily capacity of 70,000 m³ (2.5 mill.cu.ft.) were put into operation in 1940. A further two settings were put to work in 1949 and two more have recently been completed, bringing the total continuous vertical retort capacity up to 330,000 m³ (11,700,000 cu.ft.) per day. There is also a bench of Klönne intermittent carbonizing chambers in commission. Other gas-making capacity is contributed by carburetted water-gas plant by U.G.I. of U.S.A. with a total daily capacity of 140,000 m³ (5 mill.cu.ft.).

BRAZIL: The gas undertakings of Rio de Janeiro, São Paulo and Santos though inter-associated for administrative purposes are operated independently.

RIO DE JANEIRO, in latitude a little north of the Tropic of Capricorn, lies at sea level. Average temperatures range from 36° to 20°C by day and from 26° to 21°C by night. Gas is used for domestic purposes, almost exclusively for cooking and water-heating, to the extent of 80 per cent of total sales. Commercial load, mostly hotels, restaurants and the innumerable catering establishments of Rio, accounts for 13 per cent. Annual sales amounted to 176 mill.m³ (6,221 mill.cu.ft.) in 1952. The average increase in annual sales over the past six years has been 6½ per cent per annum.

Coals carbonized are now mainly of North American origin with some National and some British coals

Following are the main operating results during 1952:

1) Total quantity of coal used .. 190,515 tonnes .. 187,496 tons

2) Average proximate analyses of coals:
over the last 6 years of coals carbonized:

COALS	*American*	*Canadian*	*Yorkshire*	*Coking Slack*	*National*
Moisture	0.70%	2.30%	2.80%	2.10%	3.90%
Ash	2.60%	4.30%	4.50%	6.10%	16.50%
Volatile matter .	36.10%	38.50%	35.40%	18.20%	30.10%
Fixed carbon ..	60.50%	54.90%	57.30%	73.30%	49.20%
Sulphur	0.60%	2.51%	1.03%	0.70%	1.50%
Calorific value,					
B.Th.U. per lb	14,900	14,200	14,000	14,600	13,700
Calories per gm	8,250	7,890	7,780	8,110	7,610

3) Total gas made (volumes uncorrected).

Coal gas	92,268,779 m³	....	3,258,450,000 cu.ft.
Carburetted water-gas ..	83,899,721 m³	....	2,962,910,000 cu.ft.
Total	176,168,500 m³	....	6,221,360,000 cu.ft.

4) Average yield of coal gas

481.2 m³/tonne 17,368 cu.ft./ton

5) Average calorific value of coal gas:

1,690 kg-cal/m³ dry ...... 190 B.Th.U./cu.ft./sat.

6) Average calorific value of gas distributed:

1,320 kg-cal/m³ dry ...... 150 B.Th.U./cu.ft./sat.

Carbonizing plant consists of 6 batteries of intermittent vertical retorts mostly reconstructed to Woodall-Duckham's designs, with a total dailly capacity of 350,000 m³ (12,358,500 cu ft.) and 2 installations of Glover-West continuous vertical retorts. The first CVR installation commenced operation in 1929. It consists of 48 – 40" (122 – 102 cm.) x 25 ft. (7.6 m.) retorts in 8 settings with pressurized step-grate producers: its normal daily capacity is 92,000 m³ (3,250,000 cu ft.). This installation has given excellent service over long periods particularly during the difficult war years. From August 1940 to June 1947, a total of 2,477 working days, it carbonized 364,000 tons of mixed coals, yielding 490 m³/tonne (17,570 cu ft/ton) with a producer fuel consumption of 15.5%. Yield rose to 530 m³/tonne (19,100 cu.ft./ton) in the period October 1947 to July 1953 as coals improved in quality.

A second installation of 32 Glover-West verticals also 40" (102 cm.) x 25 feet (7.6 m.) was put into operation in April 1951. The four settings were built on the latest Balanced-Heating principle with pressurized producers. The total daily gas-making capacity of the Glover-West CVRs is 148,500 m³ (5,250,000 cu.ft.).

Carburetted water-gas production varies between 15 and 55% of the total gas manufactured. The plant is in 6 units with a total daily capacity of 538,000 m³ (19 mill cu.ft.). The two original sets were reconstructed by the U.G.I. Company of U.S.A. in 1927. Two further sets were reconstructed by the Gas Company and two Power Gas Corporation sets were installed in 1942 and 1950. Each of the latter is fully automatic and with a nominal daily capacity of 127,500 m³ (4½ mill.cu.ft.).

Metallurgical (mostly foundry) coke forms 70 to 80% of total coke [illegible] to practise careful selection of coals, and in view of the relatively small demand for coke in other directions, to regulate the balance between coal gas and water gas production both to meet peak loads and to maintain a constant supply of coke.

The total installed daily capacity of gas-making plant is 896,000 m³ (31,650,000 cu.ft.) and the maximum daily production to date (July 1953) is 565,900 m³ (19,978,630 cu.ft.).

In SÃO PAULO the coal-gas plant consists of 5 benches of horizontal retorts by Gibbons with an effective daily capacity of 100,000 m³ (3,530,000 cu.ft.) installed between the years 1912 and 1928. This is supplemented by 2 carburetted water-gas plants installed in 1906 with a combined daily capacity of 28,000 m³, one CWG plant in 1927 of a daily capacity of 28,000 m³ and two others installed in 1930 and 1946 each with a daily capacity of 60,000 m³ – a total installed CWG capacity of 176,000 m³ (6,215,000 cu.ft.). There is also a blue water gas unit of 28,000 m³ capacity and a further fully automatic CWG unit is (at the time of writing) in course of erection with a daily capacity of 105,000 m³ (3,707,550 cu.ft.).

At SANTOS coal gas plant consists of 3 settings each of 8 Glover-West vertical 20 ft (6.1 m.) retorts which came into operation in 1917 and one setting of 25 ft. (7.6 m.) retorts in 1930, with a combined daily capacity of 1,112,000 cu ft (10,800 m³). Four of these retorts were turned over to oil gas production in 1948 and four more in 1951. Supplementary diluent gas is manufactured in a number of small producer gas units with a total daily production of 11,000 m³ (1,118,000 cu ft.).

Coals carbonized in São Paulo and Santos are similar to those shown in the Table above. The climate of Santos is somewhat similar to that of Rio but São Paulo, lying some 3,000 feet above sea level, is decidedly more temperate.

Total sales of gas in the three cities reached a new record in 1952 at 8,916,788,600 cu ft. (252,316,120 m³) an increase of 3.6% over 1951.

JOHANNESBURG (South Africa) is situated just above latitude 26° S but it stands on a wide plateau 5,600 ft (1,700 m) above sea level. The climate is one in which the use of gas for cooking and water-heating, and for intermittent space-heating is particularly convenient. In typical weather, day temperature is high, rising to 80° F (27° C) in the shade but at sundow temperature falls rapidly to as low as 50° F (10° C) persisting during the night.

The rapid expansion of the Johannesburg Municipal Undertaking since 1928 is unique in the history of the gas industry. From a little over 100 mill.cu.ft. (2.8 mill.m³) gas production at that date, 1,886,427,000 cu.ft (53,420,000 m³) of gas were made in the year ending June 1952 an increase of 8.18 per cent over the previous year's total following an

[illegible] per cent on the year before that. The maximum quantity [illegible] 24-hour period in July 1951 was 6,957,000 cu. ft. ([illegible] m³).

The coals carbonized are obtained from Rhodesia (Wankie), the Transvaal and Natal with the following average characteristics:

	Wankie	*Transvaal*	*Natal*
Fixed carbon	63.2%	51.76%	55.07%
Volatiles including moisture	25.9%	35.30%	31.83%
Ash	10.9%	9.91%	13.10%
Sulphur	1.6%	0.52%	1.2 %
Calorific value gross			
B.Th.U/lb	13,300	13,100	12,800
Cal. per g.m.	7,390	7,280	7,110

The average yield of coal-gas during 1951/52 was 16,311 ft³/ton (455 m³/tonne), of coke 1,421 lb/ton (63.6%), 13.39 gallons (61 L.) of crude tar and 7 lb (3.2 kg) of sulphur recovered, all as measured under the average conditions of pressure and temperature which are 24.75" Hg (629 mm) & 65°F. Gas is distributed with a calorific value of 470 B.Th.U/cu ft. as reduced to 30" Hg & 60°F saturated (4487 cal/m³ at 760 mm & 0°C dry).

Gas is manufactured in 78 Glover-West continuous vertical retorts (54 - 40 inch and 24 - 50 inch) (137 - 102 cm. and 61 - 127 cm.) supplemented by carburetted water gas plant which in 1951/52 contributed about 9 per cent to the annual output. Additional CWG plant by the Power Gas Corporation of Great Britain came into commission towards the end of 1952.

Gas is used in Johannesburg in thousands of domestic premises, 200 factories, 30 nursing homes and hospitals, 55 hotels and restaurants, 190 blocks of flats, 82 schools and most of the Municipal Departments.

TOKIO is situated in about 26° north latitude. Average daily temperatures rise to 21°C in August and fall to 5°C in January and February. Tokio Gas Company serves a very large area extending the full length of the western shore of Tokio Bay. Tokio, Yokohama and Yokosuka are connected by high pressure mains (operating at a pressure of 7-14 lb/sq. inch (0.5-1.0 kg/cm²) with a total length of over 370 miles (595 km).

Although coke is the more saleable product of carbonization gas consumption per consumer has practically doubled since the War, as shown in the following table:

Average monthly gas consumption per consumer, 1940, 33 m³ (1165 cu ft.)
Average monthly gas consumption per consumer, 1941, 30.8 m³ (1087 cu ft.)
Average monthly gas consumption per consumer, 1952, 52.6 m³ (1858 cu ft.)
February consumption (peak month) per consumer, 1940, 37 m³ (1306 cu.ft.)
February consumption (peak month) per consumer, 1941, 38 m³ (1342 cu ft.)
February consumption (peak month) per consumer, 1953, 69.9 m³ (2470 cu ft.)

Minimum consumption per consumer in 1953 was 47.51 m³ (1678 [illegible]).

Gas manufacturing plant consists of Koppers compound coke ovens at Tsurumi, Ohmori and Suehiro Works with Koppers "half divided" type ovens at Kanayawa. Total carbonising capacity is 3,660 tons/day at the maximum. At Senju Works oil-gas plant is installed with a daily capacity of 300 kl (66,000 gallons) and similar plant is to be installed at Ohmori with a daily capacity of 400 kl (88,000 gallons) by the end of 1953. A number of smaller works in the district are equipped with horizontal retorts.

Coals carbonized are:

Indigenous:	*Washed by-product coal*	*Moisture* %	*V. M.* %	*F.C.* %	*Ash* %	*Swelling Index.* %
Heavy Coking Coals	Shikamachi	0.93	19.86	57.71	21.47	7.0
	Yatake	0.89	17.87	57.31	21.10	8.0
	Kanbayashi	0.71	20.24	56.88	22.17	9.0
	Oyubari	1.03	41.06	51.90	6.01	7.0
Light Coking Coals	Hajima	1.38	35.16	56.37	7.09	9.0
	Futago	1.16	43.67	49.49	5.68	7.0
	Mojiri	2.15	40.55	48.51	8.79	5.5
	Iwojima	1.86	41.21	47.91	5.92	3.5
	Yubari	1.16	42.51	49.68	6.65	7.5
	Akabira	2.33	42.14	49.53	6.20	5.5
	Ashibechi	2.10	42.17	49.71	6.02	4.0
	Mayachi	1.91	41.43	48.45	8.22	1.5
	Sorachi	1.86	40.08	47.61	10.35	1.5
	Sunakawa	1.87	40.08	47.18	10.87	2.5
Imported (U.S.A.)						
Heavy Coking Coal	Royalty	1.61	23.84	68.01	6.48	9.0
	Utah	3.71	37.03	49.82	9.44	1.5
	Roslyn	3.52	38.00	46.69	11.70	3.0
Light Coking	Elkhorn	2.21	36.71	54.54	6.48	1.5
	Powellton	1.51	22.32	61.75	4.42	8.0
	Cedar Grove	1.68	37.72	56.30	4.10	6.5
	Chilton	1.57	33.72	59.06	6.05	6.0
	Thacker	1.76	35.83	57.55	4.86	7.5

Leading statistics for 1952 are: –

Coal used	1,201,460 tonnes	1,182,477 tons.

Gas produced:

Coal gas	622,612,000 m³	....	21,987.4 mill. cu.ft.
Producer Gas ...	61,373,000 m³	....	2,167.4 mill. cu.ft.
Oil Gas	15,414,000 m³	....	544.3 mill. cu.ft.
Gas sold	676,626,000 m³	....	23,891.9 mill. cu.ft.

Max. daily send-out	2,561,000 m³	....	90,450,000 cu.ft.
Min. daily send-out	1,305,000 m³	....	46,080,000 cu.ft.

Declared calorific value .... 3,600 Kcal/m³ at 760 mm. 0° C dry
377 B.Th.U./Cu.ft. & 60° F. sat.

By-products:

Coke	781,593	tonnes	....	760,430 tons.
Tar	59,078	tonnes	....	58,150 tons.
Sulphate ammonia	11,237	tonnes	....	11,060 tons.
Crude benzole	22,696	tonnes	....	22,330 tons.

Gas is used for domestic purposes 62.1%, for industrial purposes, 15.6%, commercial 12.1%, Government offices and public buildings 3.5%, hospitals 1.97%, by "security forces" 4.2%.

HONG-KONG

The Crown Colony of Hong-Kong with the island of that name and the territories of Kowloon on the mainland lies in latitude 22° N. The average maximum daily temperature ranges from 87° F (31° C) in July to 63° F (17° C) in February and the minimum from 78° F (26° C) to 53° F (12° C).

There are two gasworks in the Colony, at Victoria, the capital on the Island, and Kowloon. At Victoria gas is made in Glover-West continuous vertical retorts. This installation which has been in operation since 1914 consists of 24 - 33" (61 cm. - 84 cm.) retorts with integral step-grate producers. An installation of 16 - 40" (41 - 102 cm.) retorts is now on the drawing board for Kowloon.

Coals from the Badusimila Colliery, India, are now being carbonized. An average analysis of the Poniati Seam, selected grade, is

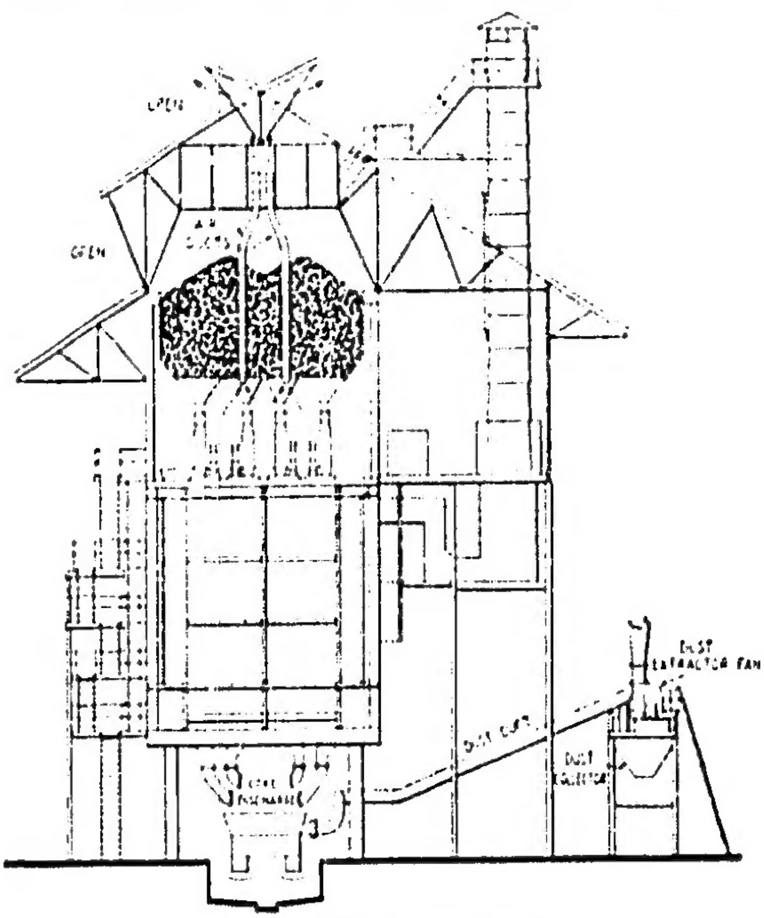
Moisture	2.0%	
Volatile combustibles	37.4%	on the dry basis
Fixed carbon	45.6%	on the dry basis
Ash	15.0%	on the dry basis

Average yields are

Gas	18,006 cu ft./ton	502 m³ tonne
Calorific value 110 B.Th.U cu.ft. gross		
	1,202 Kcal/m³ (0° C. 760 mm. dry)	
Coke	12.8 cwt/ton	64%
Tar	13 gallons/ton	58 Litres tonne

Total gas sold, 1952

Domestic	512,612,000 cu.ft.	14,517,475 m³
Industrial	25,324,000 cu.ft.	717,190 m³
Public lighting ..	35,274,000 cu.ft.	998,980 m³



Cross Section of Retort House
Building designed for Tropical Conditions

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The influence of the climate on operation at these Works is remarked upon. It is said to be noticeable only in the operation of condensers and washers. Obtaining sufficient cool water to reduce the temperatures in this apparatus to the required point is always a problem in the hot season. Unless a supply of cool water from a deep well is available, some form of water-cooling apparatus is necessary. With regard to working conditions in the retort house it is remarked that "vertical retorts are much to be preferred in the hot season owing to the much cooler working conditions resulting in considerably less sickness of the workmen as compared with horizontals".

The TROPICAL RETORT HOUSE

The accompanying drawing shows the elements of a typical design of retort plant housing which has been much used in tropical climates. It is considered necessary to provide roof covering to protect plant and workmen from heavy rain. Sides should be left open as much as possible and ample exit space should be provided in the roofing to evacuate hot air and gases from the settings.

It will be noted that ventilating ducts are provided through the coal bunkers to release hot air which might otherwise "pocket" between the top of the retort bench and the underside of the bunkers. Mechanical dust extraction plant is provided where shown with ducts leading to the point of coke discharge from the base of the retorts. These provisions are by no means confined to installations in the tropics. They will be found in most modern plants in temperate climates. But they are particularly appreciated by personnel in hot and humid climates, conducing to the maintenance of their health and contentment.

SUMMARY

The modern trend in the design of carbonizing plant, though directed mainly to the attainment of high thermal efficiency and low labour cost, has resulted in the development of plant with characteristics which are favourable to operation under tropical and sub-tropical conditions. The temperature of working platforms is reduced to the practicable limit and complete mechanization eliminates arduous manual labour.

The design of the retort house itself is modified to suit tropical conditions by the omission of side covering but with particular attention to ventilation, which though not confined to tropical conditions is particularly appreciated by personnel in hot and humid climates, conducing to the maintenance of their health and contentment.

The paper contains details of plant and results of operation at Santiago de Chile, Rio de Janeiro, São Paulo, Santos, Johannesburg, Tokio and Hong-Kong.

Resumo

A atual diretriz na elaboração de projetos de instalações de carbonização, embora visando principalmente a obtenção de elevada eficiência térmica e baixo custo de mão de obra, resultou na evolução de usinas com características favoráveis ao funcionamento em condições tropicais ou sub-tropicais.

A temperatura das plataformas de serviço é reduzida ao limite permissível e mecanização completa elimina trabalho manual árduo.

Para se tornar apropriado à condições tropicais o desenho do compartimento da retorta é modificado, omitindo-se as coberturas laterais mas prestando-se atenção especial à ventilação que embora não seja limitada a condições tropicais, é particularmente apreciada pelo pessoal em climas quentes e húmidos, contribuindo para a conservação de sua saúde e contentamento.

O artigo contem detalhes de usinas e resultados de serviço em Santiago do Chile, Rio de Janeiro, São Paulo, Santos, Joanesburgo, Tóquio e Hong-Kong.

Résumé

Les tendances actuelles dans la construction des instalations de carbonisation, dirigées surtout vers la réalisation de hauts rendements thermiques et la réduction du coût de la main d'oeuvre, ont abouti au developpement d'installations dont les caractéristiques se prêtent à l'exploitation sous des conditions tropicales ou sub-tropicales. La température des platformes de travail se trouve réduite à la limite pratique et la mécanisation complète a éliminé les travaux manuels pénibles.

La conception du bâtiment protégean les cornues lui-même est modifiée de façon à l'adapter aux conditions tropicales par la suppression des parois latérales tout en payant une attention particulière à la ventilation qui, tout en n'étant pas bornée aux conditions tropicales, est particulièrement appréciée par le personnel dans les climats chauds et humides car cela contribue au maintien de leur bonne santé et à leur bien être.

Le rapport donne des détails sur des installations et sur des resultats d'exploitation a Santiago du Chili, Rio de Janeiro, São Paulo, Santos, Johannesburg, Tóquio et Hong-Kong.